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TABLE OF CONTENTS.

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THE AMERICAN

METEOROLOGICAL JOURNAL.

VOL. VII. ANN ARBOR, JANUARY, 1891. NO. 9.

ORIGINAL ARTICLES.

THE NEW ENGLAND METEOROLOGICAL SOCIETY.

The seventh annual meeting of this society was held in Boston October 21, 1890. After the usual business incident to an annual meeting, the special topic of Tornadoes was discussed.

Prof. W. M. Davis spoke upon the features of Tornadoes and their distinction from other storms, considered in connection with the tornado at Lawrence, Mass., July 26, 1890. He said:

Tornadoes are violent, local progressive whirlwinds, having a general indraft from all sides, rapidly increasing in velocity and taking on a true rotary motion near the centre, where a column of dust and rubbish is raised to meet the funnel cloud that hangs from the great cloud mass above; the breadth of their destructive action is generally less than a thousand, and is often less than five hundred feet. They sometimes occur in groups, and are nearly always generated in the southeastern quadrant of a general cyclonic storm.

The whirling of tornadoes has long been on record, not as a theoretical conclusion, but as a fact of direct observation. As long ago as 1687 the Rev. Mr. A. de la Pryme described a "spout" that occurred at Hatfield, England. He wrote: "The wind thus blowing soon created a great vortex, giration and whirl among the clouds, the center of which every now and then dropt down in the shape of a thick long black pipe, commonly called a spout; in which I could plainly and most distinctly behold a motion, like that of a screw, continually drawing upwards and screwing up (as it were) whatever it touched." From this

time on the more explicit accounts of these storms furnish plentiful reason for believing that de la Pryme's spout was in no way exceptional in its whirling motion. Coming at once down to the present time, Mr. Peter Holt, who saw the Lawrence tornado of last July from a little north of its path, made direct statement as to its whirling motion, when questioned as to what he had seen by Mr. Hiram F. Mills, member of our society, shortly after the storm. On telling Mr. Holt that there were some persons who doubted the whirling motion in the Lawrence tornado, he said to me that that mattered nothing to him; he saw it whirling.

Some fifty years ago Espy maintained that tornadoes did not whirl; this, and the corresponding belief that our larger storms have also only radial winds, seem to be the only considerable errors made by this able meteorologist. Tornadoes all whirl, and this for a reason that was clearly stated in answer to Espy, when he advocated his theory of radial indraft at a meeting of the British Association in 1840. One Mr. Smith then explained that "from the principle of the conservation of areas, it was perfectly certain that if a storm was caused in the manner supposed by Mr. Espy, there must be a rotation greater or less, in the center. Because, unless the motion of all the currents was accurately directed to one point, or at least their moments in a horizontal plane were equal to zero, which was infinitely improbable, a motion of rotation must be the result." This Espy acknowledged to be correct and admitted that it is "highly probable that spouts sometimes whirl one way and sometimes another; but generally neither way; and in all cases the whirl, if any, would only be perceptible very near the centre." The right-to-left direction of rotation, since then discovered to prevail among the tornadoes in this country, is now explained by Ferrel as an immediate result of the origin of tornadoes within our large cyclonic storms, whose rotation is without exception from right to left; and it is interesting to remember that all the accordant rotations and revolutions of the sun, the planets, the satellites, our cyclonic storms and our tornadoes, are simply a persistent inheritance from the initial moment of rotation that is rationally assumed to have existed in the primitive nebulous mass from which it is supposed that our solar system is developed.

The storm at Lawrence was typically a tornado not only in its whirling, but also in nearly every feature by which tornadoes

are characterized. It was formed within a large region of warm, damp, southerly winds, in the southeastern quadrant of a cyclonic storm, whose center was at that time in the valley of the St. Lawrence. The tornado moved in a north-easterly track at a rapid rate, something like fifty miles an hour. It whirled from right to left, as is known not only from Mr. Holt's observation to this effect, but also from the position of many overturned trees, and from the way in which houses were moved and rubbish was blown about. The *southern* windows of a house on the southern margin of the track of destruction were broken by fragments of houses that stood to the northwest of it. A railroad gate-tender's house, close to the northern side of the track, was moved westward. The elaborate map of broken-down houses and overthrown trees made by Mr. Mills adds many confirmatory details, all pointing to this conclusion, as he will more fully state for himself. The amount of destruction was such as a well-developed tornado usually accomplished; although in this respect the storm does not seem to have been of the greatest strength. The intermittent action of the whirl, nearly always found when the track is carefully studied, is reported at Lawrence also. Several observers in the neighborhood recorded exceptionally heavy rain, such as generally accompanies tornadoes, although not immediately within their whirl.

The Signal Service *Weather Review*, for July, gives an abstract of several accounts of the tornado, and copies what purports to be Mr. Mill's map; and on the same page with the quotation of Mr. Holt's statement of what he saw, the following conclusion is presented. "There are a few trees on the left-hand side which indicate a counter-current or a pushing through of the current on the right side, but the general position of the trees is, just as in the case of the houses, toward or in the direction of the tornado." This conclusion appearing as an official report is not creditable to the Signal Service; especially as in connection with it, the map made by Mr. Mills, referred to above, is miss-copied in an important and essential particular, although his name is still printed with it, and no statement is made of the change from the original. The change from the original map, of which a blue-print has been sent to our Society, consists in the omission of the two lines drawn by Mr. Mills as marking the lateral limits of the destruction of the tornado and the insertion of a new line, not on his map, marked "central line of tornado." If this new line had been placed half way

between the lateral lines of the original, its addition might have been excused; but it is drawn so as to pass at one side of the map completely *outside of the northern margin* of the track as defined by Mr. Mills' observations, and leave the gate-tender's house, mentioned above, on the right of the so-called center line. It is manifest that this change is a serious one, as far as the problem of the tornado is concerned; for on the theory of a whirl, the house on the north or left side of the track would be moved westward, naturally enough; while on the theory of an inward and forward rush of air from either side, it would not be so carried if it stood on the left side of the track. I hope to see an explicit correction of this unauthorized change in a later number of the *Weather Review.*

It is proposed to publish a full account of the Lawrence tornado in the "Investigations" of the Society for the current year.

Professor Davis' statement was illustrated by a number of lantern views of the effects of the Lawrence tornado, from photographs lent by Mr. Mills.

Mr. Hiram F. Mills, of Lawrence, Mass., also discussed the report of the U. S. Signal Service upon the Lawrence tornado. After expressing disapproval of the methods adopted by the Service in this investigation and of the alteration of this map, he proceeded to discuss the conclusion published in the *Monthly Weather Review,* as already quoted by Prof. Davis. He said:

Putting the center line where the facts presented show that it must have been let us look at the facts and see how much truth there is in the above quoted statement.

If the results were produced, as assumed by the Signal Service, by a pressure of wind along a path with side pressures towards the center, we might represent the result approximately by dividing the path into three sections: the middle third having directions parallel with the axis and the two outer thirds having directions about 45° with the direction of the storm, thus:

If produced by a whirl from right to left the general directions would be as follows:

The southern section would not characteristically differ in either case. The middle section would if produced by the whirl have trees pointing northerly nearly at right angles with the path. The facts are that in this middle section there are eleven trees which are nearer parallel than at right angles, and thirty-

nine trees that are pointing northerly or north-westerly and are more nearly at right angles than parallel with the path; that is, 78 per cent. are as they would be if left by a whirl and as it would be impossible for them to be without a whirl.

In the northern third of the path of destruction the general position would be pointing outward and backward about 45° with the axis if produced by a whirl. There are eighteen trees out of forty-four that have directions nearer an inward forward direction than an outward backward direction, or 60 per cent. are in a direction nearly opposite that which they would have if there were no whirl, and were in positions they could not take without a whirl.

There are twenty-nine trees in the northern two-thirds of the area of destruction which might have had their position if there had been a stream of air rushing north-easterly, and sixty-five trees or 70 per cent. of the whole number in positions entirely inconsistent with such a stream, and just as they would have been with a whirling motion in the direction in which it was seen to whirl by a careful observer stationed in front and beyond its northern edge.

But there is another point to be noticed: of the twenty-nine trees in the direction of the stream nine were not uprooted, but were broken off or bent over; one of them is shown in a photograph, which Prof. Davis has here, twisted more than a quarter round, but still lying nearly in the direction of the path: and others are among those which fell after the first action of the whirl,—shown by their being on top of those turned more westerly,—and may have been bent or broken by currents of air flowing in behind the whirl as it sped on, a mile in a minute, or, which appears to me more probable, may have been loosened by the front of the whirl and thrown down by its rear.

Now we are able to judge how much truth there is in the general summing up of the Signal Service report in regard to what is presented in the Park. They say: "There are a few trees on the left-hand side which indicate a counter-current or a pushing through of the current on the right side, but the general position of the trees is . . . toward or in the direction of the tornado."

We must regard 70 per cent. as more than a "few" and the word "general" would require more than 30 per cent. to give it significance.

No one could have seen the trees as they lay in the Park; and

no one, acquainted with the path taken by a particle in a whirl moving along a long line, can study the map of the trees, with the facts that were reported, without seeing that the destruction was caused by a whirl, or a series of whirls, and that the whirling was in the direction seen by Mr. Peter Holt.

The question may well be asked, why was not more damage done west from the Park by the northerly part of the whirl in its westerly or backward motion? This might receive sufficient answer from the facts that the houses destroyed on the south side of Springfield street were evidently in the southerly limit of the whirl, and the northerly limit extended beyond the houses on the north side of the street, where there were generally no houses or other obstructions until we reach the large two story house near Union street which was moved westerly eight feet.

But there are other considerations. If the whirl has a velocity about its center equal to that of the center in its path there will be no backward motion. If the whirl has a velocity two times its velocity in the direction of the storm all particles in the southerly (nearly two-thirds) portion of the path are moving for about three-quarters of the time with a destructive velocity nearly equal to the actual velocity in the whirl—while for about one-quarter of the time the particles in the northerly one-third of the path have a retograde motion which much reduces their destructive velocity.

The work that can be done by the forces in the northern part of the path is but a small fraction of that which can be done in the southerly portion.

Nearly all of the work is done by the front of the whirl; but in a grove of trees it is evident that the front-half may break some of the roots of a tree without overthrowing it, and the rear half of the whirl may complete the overthrow in a direction more nearly that of the general path of the storm. This is probably the reason why some of the trees that were on top were more nearly in this direction than those which fell first.

The form of the curves made by the overturned trees, as shown upon the map, indicates to me that the rotary velocity of the whirl was more than two times and probably more than three times the progressive velocity of the storm.

Mr. H. H. Clayton said the phenomenon which most forcibly attracted his attention when examining the track of destruction of the tornado was the sharp distinction of the destructive

winds as the tornado descended toward or rose above the earth's surface. Where the tornado crossed the river before entering the town the top of the first tree injured was broken off almost as smoothly as if done with a pruning knife and the branches bent in the direction of the tornado movement, while the branches immediately below the broken ones showed no signs of injury. Again when the tornado left the earth the last damage done was to the top branches of a large oak which was broken off. The tornado then traveled for a quarter of a mile over a thickly settled part of the town with light frame structures and outhouses without doing a particle of damage. Then as it began to come down it first took the highest part of the steeple off the front end of the church, tore the rear end of the roof of the church off, and a little further on reached the earth's surface and continued onward for nearly a mile with great destruction. The last object damaged was again the top of a tree as it left the earth's surface, and the branches were carried in the direction of the tornado movement. Mr. Clayton also spoke of several groups of trees in which each tree in the group lay over the other in such a manner as to show a progressive change in the wind direction, and he thought demonstrated a rapid rotary motion of the air near the center of the tornado. Many objects near the outer limit of destruction appeared to indicate that at the outer edge of the tornado the inward rotary motion toward the centre was stronger than the rotary motion of the air which only became very great near the center. Most of these outlying objects on the right of the path of destruction, and also on the left side when the tornado was developing in energy were inclined inward and also in the direction of the tornado motion indicating a stronger destructive power by the air in the rear of the tornado where the air was probably influenced both by the progressive motion of the tornado and the indraught toward its center.

The Secretary read from advanced sheets of the *Monthly Weather Review* a description of the tornado at Wilkesbarre, Pa., and also the following paper prepared by Prof. H. A. Hazen:

I have been requested by your Secretary to prepare a short paper on the subject which is to come before you at your fall meeting. I am gratified that your society is to discuss this question, as it seems to me of great importance, and is one upon which there are unfortunately too many erroneous ideas cur-

rent. The public press in connection with the Lawrence tornado have made serious mistakes regarding the severest that have occurred in New England. In one statement a notable tornado is placed at Pittsfield, Mass., in June, 1879. There is no record of a storm on this date either in the *U. S. Weather Review* or in Finley's list of tornadoes. Inquiry has developed the fact that there was a tornado in this part of the state on July 16, 1879. It was not a very severe one, however, the loss of life being one killed directly, and one thrown from a buggy by a runaway horse, and of property $20,000. In the public press I have seen no mention of the Wallingford, Ct., tornado of August 9, 1878, though it is by far the most severe in New England since 1840. Here there were thirty-four persons killed and $200,000 of property destroyed. This brings us directly to the most important part of this subject from a practical stand-point, namely, the loss of life and property. We are accustomed to carry in mind only the most severe tornadoes like the one at Louisville, Ky., on March 27 of the present year, where 76 were killed and over $2,000,000 of property were destroyed. We are not impressed with the fact that on an average not more than one person loses his life in each tornado. It is a matter of frequent wonderment that though thousands of persons are exposed to the fury of such a blast so few are killed; for example, at Wilkesbarre, Pa., on August 19, 1890, about 200 houses were utterly demolished and yet only sixteen people lost their lives. The reasons are, (1) there is ample warning to almost every one from a terrible and unmistakable *roar* which forces people to seek the cellar for safety. (2) The exceedingly narrow path of great destruction. We are told that the average width of tornadoes in this country is half a mile and the length twenty-eight miles. This estimate is exceedingly exaggerated; the most severe tornadoes rarely have a width of more than 500 feet and a length of great destruction more than a mile. (3) I think houses are not very often crushed down, though this phenomenon seems to have been largely noted at Wilkesbarre. If a house is blown over the inmates may be left unharmed, and this experience has been repeatedly narrated.

The reason we sometimes consider the loss of life much more serious than it really is is because the whole number killed are reported from each of the several towns in the neighborhood. In the Louisville tornado one paper reported thirty deaths in a single

county where afterwards it was found that none had lost their lives. It will be understood that I am not trying to belittle the terrible nature of these outbursts but I am asking that we may have correct views, for correct views are bad enough.

After the Lawrence tornado I saw that an insurance company was doing quite a business insuring against tornado losses. This question, it seems to me, comes home to every householder and, what is singular, he rarely asks as to the amount of risk there is from this violent storm. Certainly we may say that in New England a man throws away every cent that he puts into tornado insurance. The question, however, is not quite so easily settled in the Mississippi valley and other parts of the country. I am not criticizing the western tornado insurance company, but I believe they have very exaggerated notions of the risk from tornadoes, and have put it from 15 to 20 times too great. The cause for this may be found: (1) in the fact that reports of loss from tornadoes have included loss to crops, orchards, fences, timber, etc., by rain, hail, flood, etc., that accompany the tornado. Of course in tornado insurance the direct loss to structures is the only one to be considered. (2) Even these losses have been greatly exaggerated; in one case I have in mind the reported loss was multiplied by twenty-five on the plea that all the loss had not been reported. A careful study of this question has been made and it has been found that the average loss from tornadoes and destructive storms in this country during the last eighteen years has been less than $15,000 for each. The Lawrence tornado ranks between two and three on a scale of three. There have been but about sixty of class three in eighteen years. Perhaps the best idea regarding the loss from destructive storms may be had by comparing it with the fire loss. During six years including 1883-4 (the years having the worst tornadoes of any in the eighteen) the loss from fire was fourteen times as great as from tornadoes, and this too in the fifteen distinctly tornado states.

Taking the part of the country visited at one time or another the proportion would be much less, that is, the loss by tornado would be much less.

There are just two points I wish to present from a scientific stand-point and I will put them in the form of questions. First. Is there a violent uprush in the center of a tornado? Second. Is there a whirl in the tornado cloud? The first of these may be accepted in a limited way; there seems to be ample evidence

that good witnesses have seen what appeared like a steady flow of mist or white steam in the centre, but it seems as though the question of a violent uprush of timbers, trees, etc., in the center of the cloud and nowhere else is by no means settled. If a cloud passes an observer at a mile a minute I think he would hardly be able to distinguish between objects carried up in a violent uprush and on by a powerful push. The second point is open to still greater doubt, though I presume that not one who hears this but has made up his mind that there must be a whirl. The reason for this opinion it is not for us to seek. Persons on the south side of the path see debris carried violently forward and a very little imagination is needed to make them go in a whirl from right to left. The evidence against the whirl is almost conclusive, as I think. First. No one, as far as I know, has seen debris carried to his right while standing on the north. Second. The uniform evidence, with a single exceedingly doubtful exception, is that the debris left by a tornado shows a powerful current from both sides toward the centre. There are freaks in every tornado which seem to show a momentary breaking through of the current on one side to the other but the general testimony is one way. Third. We have many eye-witnesses, two at Lawrence, who say they saw the cloud advancing with a rolling motion on a horizontal axis nearly at right angles to its path. Fourth. The earliest drawing of a tornado cloud shows no such whirling or even approach to it. I believe that no point regarding a tornado is so important as this, and I hope that before many years have elapsed to obtain indisputable evidence regarding it. It is hopeless for an eye-witness to obtain any positive knowledge if he is on the south side, but on the north side he ought to see timbers, etc., moving to his right; though even here care must be taken not to be deceived by the appearance of timbers near the center seeming to go ahead faster because they have a greater velocity there; the virtual effect of this would be to make objects on the north edge appear to go to the right hand. One great source of uncertainty in tornado observations has been the mingling of observations made on the south side with those on the north and from considering observations by persons 1,000 feet from the centre. No one should undertake to make detailed observations unless less than 500 feet away.

The Secretary (Prof. W. Upton) in commenting on this paper, remarked that he was sure that there was no *intentional* mis-

representation of the reports on the part of the U. S. Signal Service, but he could not agree with the conclusions reached, nor with those advanced by Prof. Hazen in his paper. He had studied theoretically the different positions in which trees should be thrown down by a tornado on the suppositions of no whirl and of whirls either clockwise or counter-clockwise. Comparing the theoretical results with the reports of the Lawrence and Wilkesbane tornadoes, he found that both of these tornadoes strongly confirmed the supposition of a whirl counter-clockwise.

THE METEOROLOGICAL OBSERVATORY RECENTLY ESTABLISHED ON MONT BLANC.*

By A. L. Rotch.

It is generally conceded that the future progress of meteorology depends chiefly upon a study of the upper regions of the atmosphere. Thus the vital, and at the present time, disputed question as to the rate of the vertical decrease of temperature in cyclones and anti-cyclones upon which rests much of our theory of the general circulation of the atmosphere, and, hence, our deductions expressed in weather forecasts, can only be settled by simultaneous observations at high and low altitudes.

Disregarding balloons as unavailable for this purpose, we must turn to the mountain stations for whose establishment and maintenance large sums of money have been expended by various countries. Until recently the highest meteorological station in the world was in the United States, on Pike's Peak, at an elevation of 14,130 feet above the sea, while among the dozen or more European stations the loftiest has hitherto been on the Sonnblick in the Austrian Alps, at an elevation of 10,170 feet. (See this Journal, May, 1888, for a description of this station).

The French, however, who have contributed more than any other nation to the study of mountain meteorology by their fine observatories on the Pic du Midi, the Puy de Dôme and the Mont Ventoux, may now claim what is probably the highest meteorological station in the world in the one which has just been established on Mont Blanc at an altitude of about 14,320 feet above sea-level.

The summit of Mont Blanc, rising to the considerable height

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* Read before Section A of the British Association at Leeds, September 8, 1890.

of 15,730 feet and dominating the adjacent peaks, seemed to offer a desirable site for a meteorological station, and here M. Joseph Vallot, a French scientist and alpinist, determined to locate one. In order to demonstrate the possibility of sojourning at such a height, M. Vallot, accompanied by M. F. M. Richard, the maker of the registering instruments used, in July, 1887, remained three days in a tent on the summit conducting meteorological and physiological observations. The erection of a permanent building on the summit being rendered impossible

THE OBSERVATORY ON MONT BLANC.
FROM THE NORTHEAST.

by the shifting snow which covers it, the site chosen was at the Rocher des Bosses, at the foot of the Bosses du Dromadaire, about 1,450 feet below the summit.

The cabin was designed to give a maximum of strength with a minimum of weight, and to serve not only as a meteorological observatory and physical laboratory, but also as a refuge for tourists. It was constructed at Chamonix last winter, with numbered parts, then taken apart and carried piecemeal by the

guides and porters in about 120 loads of 35 pounds each to its present position at the Rocher des Bosses where it was put together this summer. The cost of the construction at Chamonix was only $160, but the transportation, which was mostly done gratuitously by the guides, the erection and furnishing of the cabin increased this sum to about $2,000, exclusive of the cost of the instruments, which has all been paid by M. Vallot. The cabin was completed early in August, while the writer, through the courtesy of M. and Mme. Vallot, was stopping with them.

The cabin is of wood, 10 by 16 feet, strongly braced and clamped by irons, and having the sides and the roof covered with tarred felting. The floor beams, which rest on a fairly level rocky foundation, elevated above the usual snow level, project at each corner and at the sides, and a dry wall of stone laid up upon them serves to anchor the building, whose stability has been proved by the gales which it has withstood. It has been protected from lightning as well as possible with the poor "ground" available. The interior of the cabin is divided into two rooms forming the observatory and refuge before mentioned. The former, in addition to the usual direct-reading meteorological instruments, is completely equipped with the registering instruments of Richard brothers. These are a barograph, already installed in a cavity in the stone wall, a thermograph and hygrograph to be placed in an isolated shelter, a recording snow gauge, integrating and aspiration anemometers and a recording wind vane, all exposed on the roof, besides other direct-reading and registering apparatus for experimental meteorological, physical and physiological work. The instruments which register the chief meteorological elements require to have their clock movements rewound and their register sheets changed but once in fifteen days, during which time it is expected the cabin can be visited so that it is hoped continuous records may be obtained for at least four consecutive months. On account of the advance of the season and the difficulties attending the first exposure of some of the instruments the installation will not be completed this year.

A similar cabin is now being built at Chamonix for M. Janssen, the French physicist, and will eventually be re-erected at the Grands Mulets at an altitude of 10,000 feet. M. Vallot has already in operation in Chamonix (altitude 3,500 feet), a meteorological station provided with some instruments similar to those at the Cabane des Bosses. The vertical difference of alti-

tude between these two stations is approximately 10,800 feet, and the horizontal face about 33,000 feet. The proposed scheme of stations includes a thermograph on the summit of Mont Blanc (15,730 feet), one on the neighboring Aiguille du Gouter (12,700 feet), a barograph and thermograph with direct-reading instruments at the Grands Mulets (10,000 feet); and at the inn at Pierre pointue (6,700 feet). Instruments will be placed in the open valley at Sallanches (altitude 1,800 feet), and on the Flegere (5,900 feet), on the south side of the valley, to study the local effect of exposure.

It cannot be denied that such a series of stations will be of the greatest value in contributing to our knowledge of the meteorological conditions prevailing from the ground up to a height of three miles. The few observations from the summit of Mont Blanc which have already been reduced show that the diurnal period of the pressure presents but a single maximum and minimum, while that of the relative humidity is nearly the reverse of what is obtained at low levels. The actinometric and polarimetric observations at this altitude will be of special value. It is the intention of M. Vallot to publish shortly the corrected and reduced observations which he has made on Mont Blanc and at Chamonix.

The two cabins at the Grands Mulets and at the Rocher des Bosses will be open to persons who may wish to undertake investigations. That at the Rocher des Bosses has already been utilized by M. Janssen who, after being conveyed thither in a species of sledge, remained several days awaiting fine weather, and was finally drawn up to the summit in order to continue his spectroscopic observations commenced at the Grands Mulets two years previously.

THE GERVAIS LAKE TORNADO: IS A MODERN FIRE-PROOF BUILDING TORNADO PROOF?

By P. F. Lyons,
Observer, Signal Service.

The Tornado.—About 4:18 P. M., 90th meridian time, a gale of considerable force with thunder and lightning, rain and hail, was reported to have commenced near Snail Lake in Mounds View township. From there it moved southeastward three and a half miles to a point in the northern portion of the town of Little Canada, and about 1,000 feet west from the northern end

of Gervais Lake. These points are respectively eight and four and a half miles to the northward of the city of St. Paul,—all are in Ramsey County, Minnesota. At Gervais Lake it developed to a tornado that, while anomalous in its course, S. 25° E., was unmistakably a genuine "twister." The area over which it left unmistakable evidences of its character, and over which the writer went on the following day, was scarcely more than half a mile in length, four hundred feet wide at initial and eight hundred at terminal points. The topography was rather irregular, about one-fourth of being marsh that intervened nearly midway between a strip of table land at the initial and a knoll near terminal points. Nearly the entire belt was fringed on the east by Gervais Lake, and on the west by an open field, then some "scrub" trees and last, a thick grove of tamaracks. All the buildings within it were eight farm houses or cottages and about the same number of outhouses, made of wood and frail in structure, and all these were absolutely torn into slivers and the debris scattered in every direction,—to distances however, not to exceed eight hundred feet, as no evidence could be seen to show otherwise. The Schurmaier and the Goode cottages were the most pretentious of the houses destroyed. They stood just on the edge of the lake and with their destruction the violence, it seems, abated, for the tornado lifted these and crossed the lake in an easterly direction. It dipped down again, it was said, at a point about a mile away, and partly destroyed a small dwelling. After that and for many miles to southeastward strong "gales" only were experienced, a calamatous disaster on Lake Pepin being the result where an excursion steamer was capsized and about one hundred of the excursionists drowned. Of the people in the Schurmaier cottage five immediately lost their lives, three of the bodies being afterwards found in the lake, and about twenty were more or less injured, one of whom died. The total loss in buildings, crops, etc., was estimated at from $100,000 to $200,000.

The trees were either uprooted or their trunks broken or twisted and prostrated. Those on the right of the central line of progressive movement were inclined southeastward, those on the left northeastward, and those twisted gave evidence that the twisting force was in a direction the reverse to the movement of the hands of a clock. Nearly all were stripped of foliage and a portion of the bark, but those barked immediately adjoined the destroyed buildings, and the barking was well up towards the top of

the trunk, being, no doubt, the result of blows from flying debris. The bark on that portion of the trunks of all trees about midway from the ground to the fork remained the same as before the tornado. Shrubbery and garden plants suffered as did the trees; all appeared parched as though a wave of fire had passed over them. Quite a number of cottonwood trees, each twenty or more inches in diameter at base, grew around many of the destroyed buildings; their limbs were torn off, but that was all the injury done to them.

Dead chickens and other fowls were found here and there and many partly plucked. The water in Gervais Lake was drawn up on the bank to a height of from two to three feet above its normal level.

To the rear of the first house destroyed, near the upper end of the lake, is an open field. At a distance of from five hundred to eight hundred feet behind the house and over the field many parts of its wreck were strewn, and numerous sticks of broken timber were found firmly thrust into the ground. One stick was found that measured one and a half to two inches thick and thirty long, forced in the ground to a depth of eighteen inches. These sticks were unquestionably parts of the wrecked building. The smaller and lighter end was invariably thrust in as stated, showing that there was a force besides gravity at work. They inclined outward from either side of the tornado's central line of progressive movement at angles varying from 30° to 70° from the vertical. Sticks and timbers were similarly stuck from there down to the middle of the area of destruction, but that field is particularly worthy of attention, for it proves that while there was a powerful upward movement in front, the downward one in the rear of the destroying vortex was of some power too. The only structure that remained intact in the destroying area was a small rustic garden ornament or flower stand. It was a frustum of a cone about three feet and a half in diameter and the same in height. The outside was a shell of rather irregularly rounded stones or "boulders," placed one over the other without cement or mortar; the interior was filled with earth. A collection of ice about twelve by twelve and seven feet high also remained undisturbed, but not a vestige of the framework that protected that ice remained. The blocks were perhaps twenty-inch cubes; those on top, though not apparently frozen to the adjacent ones, were not disturbed, yet pianos, wagons, farm implements, stoves and metal cooking utensils were badly broken

and hurled in every direction. No doubt the breaking and hurling of these comparatively strong and heavy articles was greatly due to their being in buildings that were lifted up, twisted into fragments and hurled as stated.

Is It Possible to Construct a Building That Will Be as Safe against a Tornado as against Fire?—Cognizant of the enormous power manifested by the tornado in Marshall county, Kansas, May 30, 1879, reference to which is made by Lieutenant Finley in his book "Tornadoes," page 86, it would certainly be the height of folly to predict, much more to stake money on, the stability of a modern building, such as will be mentioned further on, for it would no doubt be partly, if not entirely destroyed. I must conclude that the advice under the caption "Protection," page 43 of the same work, is the most practical, surest and plainest safeguard yet offered; no prudent person, no matter what the environment or circumstances, should fail to heed it. On page 68 reference is made to the fear entertained of the awful destroyer, and he adds that a great deal can be accomplished towards allaying this by a dissemination of practical knowledge concerning storms, and by a general effort among intelligent people to inform themselves. A desire to supplement him in that respect has prompted me to write this paper, and to that end the "village oracle" is entitled to a passing notice, for there is scarcely a village without one. Every city has one or more of these self-styled wise "prophets," who delight in trying every now and then—lest the public may be unmindful of their presence—to cause a feeling akin to awe by predicting some great occurrence. The cyclone is their favorite hobby; any other word wouldn't sound sufficiently turgid. Then they, with other sensationalists, have recently augmented the tornado's power so greatly as to make the imaginative and timid think that it is a realization of Archimedes's lever, provided with the necessary fulcrum. That class manage to get themselves spoken of frequently and they acquire ephemeral or even perennial notoriety; but what is the result to the timid, especially to women and their offspring, the physician perhaps can answer. I believe that such awful force as was evidenced in the tornadoes in Marshall county, Kansas, and a few other places, is exceptional, and that man, in his efforts to prevent or mitigate the ravages of a foe almost as insidious as, but more destructive than, that aerial monster, fire, has a partial protection in the modern fire-proof buildings, many of which have been lately

erected in most cities of importance. They are structures of great weight and strength; both exterior and interior walls must necessarily be massive in order to sustain the great iron beams, concrete, terra cotta and tiling that constitute their floors and partitions. They certainly combine the two principal factors requisite to resist the force under discussion. In the case of the pile of ice and little mound which withstood the force as stated, when everything else all around and about them was destroyed, and shrubbery torn from the earth, the security was due to compactness and weight. As to adhesion, it amounted to considerable in one and to nothing in the other. That is what leads me to believe that many of the recently constructed fire-proof buildings in St. Paul, and undoubtedly there are many more and perhaps even better constructed ones in other and larger cities, would stand as good a chance as the things just mentioned. Such buildings might be partly demolished by some of the forces that lifted iron bridges, but even to such force they would prove resistant and avert further destruction. I am fully convinced that they would withstand the force that calls out this article and also the majority of others like it. In further support of my convictions I make the following extracts from the *Monthly Weather Review* for March, 1890, relative to the tornado at Louisville, Kentucky, March 27:

"Churches, halls, warehouses and other structures having but little interior support suffered the most. The destroyed buildings were as a rule of very unsubstantial character, being mainly ordinary brick dwellings, small stores and warehouses. The Fort Nelson building, Seventh and Main street, is the most notable exception to the general destruction which marked the path of the tornado. This structure is a well-constructed six-story building and by its greater height than those surrounding it, was more exposed to the storm's fury. Despite the fact that it was directly in the storm's track, and that all other houses on either side were wrecked, it escaped with the loss of its windows." Further interest in this matter led me to make reliable inquiry about that building, with this result: "The Fort Nelson building is classed as a modern fire-proof structure of brick, with stone front. It is used as a wholesale dry goods house, and the floor, beams and joists are of iron. Its dimensions are about thirty by seventy feet. It occupies a comparatively isolated position, being much higher than any adjacent building, and it stands almost directly in the center of the storm path. Its

immunity from destruction is one of the most remarkable features of the storm, as everything else in the immediate locality was totally demolished." If the dimensions of that building be considered it will appear a pigmy, if the use of the expression be allowed, in comparison with many buildings of like character, both public and private, that cover from a quarter to a half, or even an entire, city block. Indeed, the point may be raised, will not many of the large ordinary brick or stone stores, the floors of which are heavily loaded with merchandise, serve as a modifier, if not something more to, the tornado.

The writer has not heard of another instance in which the class of buildings of the Fort Nelson character has been seriously injured by wind of any kind. They have been tested, though, and the result is known. Let us sincerely hope, if not pray, that similar tests will not come again, but until such be the case the writer must believe in their substantial immunity. The result of an interview with survivors of the tornado shows that ten persons were in the Schurmier and fifteen in the Goode cottages during the storm. Of those in Goode cottage about eight took refuge in a small cellar under the pantry, the rest were on the first floor. According to their statements the work of destruction commenced by the furniture and other household articles flying back and forth in the rooms, after which the side walls of the building seemed to approach each other, then the house was lifted and opened, when it dropped them out nearly in the exact locality where they were before the casualty. Among those taking refuge in the cellar were Dr. Howard T. Eachus and wife. They evidently were less excited than others, and it is to them I owe the statement relative to that house. They also stated that while in the cellar during the period of destruction there was great difficulty experienced by all in breathing; there was a gasping for breath and covering the mouth and nostrils with the hands, as if to either filter the air or mitigate some choking sensation that was common to all. One lady—Mrs. Goode, I think—pressed her mouth firmly against a pillow and breathed in that manner. He further stated that light rain with a few hailstones preceded and excessive rain accompanied the destruction, which was all over from three to four minutes from the time it began. He did not see a funnel cloud and his position was not the best for observing one, but the clouds in all directions seemed to have suddenly separated into small fragments and rushed to a common center in his

locality. As a remarkable incident he remembers finding a part of his buggy a short distance west from where he left it. The body or upper part was gone, only the iron axles and springs remained uninjured, and it was very remarkable that while the nuts on the ends of the fore axle were not disturbed the hubs were gone. One hub and nut remained on one end of the hind axle, neither nut nor hub on the other. The nut was not screwed but forced off, the screw threads being torn away. The presence of the funnel cloud was vouched for by numerous spectators, and the time of beginning and ending of destruction was from 6 to 6:15 P. M., seventy-fifth meridian time. That is the period during which nearly total darkness prevailed, at the end of which a soft sunlight and almost a calm atmosphere revealed what was done.

ST. PAUL, MINN., August 15, 1890.

RAINFALL IN MICHIGAN—ANNUAL.

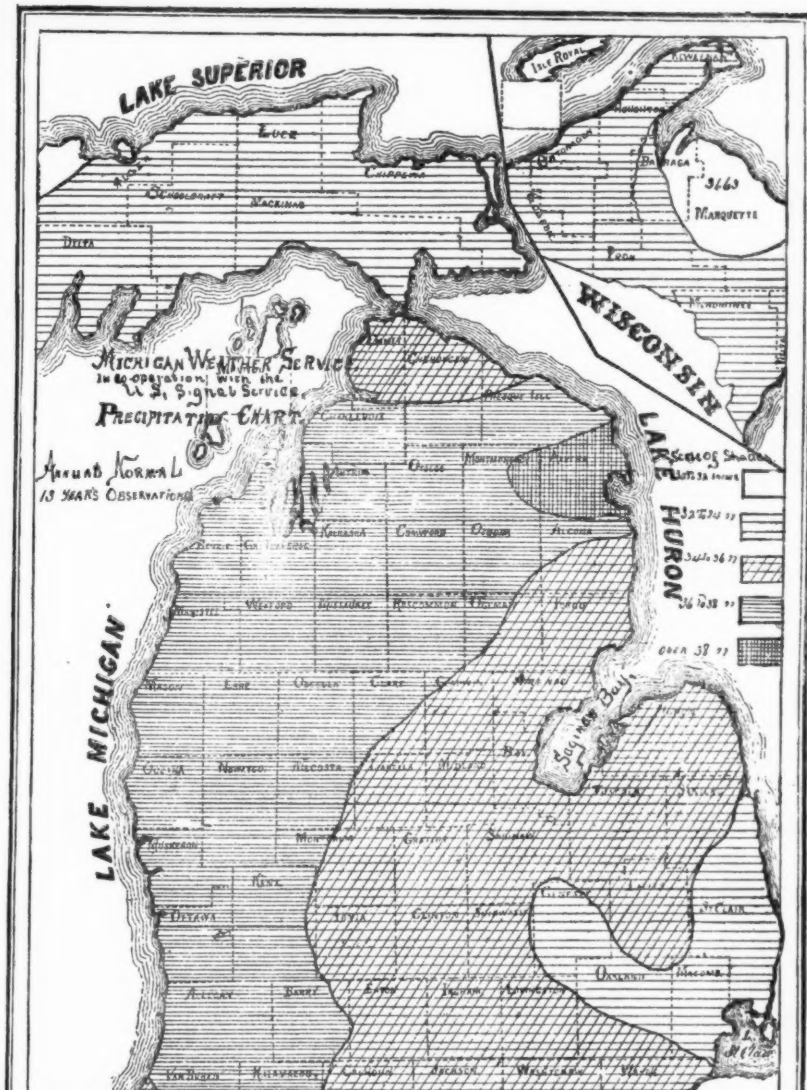
By N. B. CONGER,
Director State Weather Service.

As might have been anticipated from the charts that have been published, the heaviest portion of the precipitation of the state will be found on the west half of the Lower and the lightest in the Upper Peninsula.

The average total rainfall for the year ranges from 43.40 inches in Berrien county to 31.63 inches at Marquette, Marquette county. The lightest rainfall for the southern portion of the state will be found in the extreme east central portion, where the amount averages between 32 and 33 inches.

There is a difference in the normal rainfall in the northern and southern portions of Berrien county of 8.61 inches, there being a small district in and about Benton Harbor where the rainfall is considerably less than for the surrounding country. The counties of Alpena, Berrien and Branch have the largest annual rainfall of the southern peninsula.

The cause of the heavy rainfall on the west side of the state is undoubtedly to be found in the prevailing southwest winds of the state, as has been intimated in previous papers, and it shows more plainly in the consolidated annual rainfall than in any of the monthly averages.



LAKE SUPERIOR
ISLE ROYAL
MARQUETTE
WISCONSIN
LAKE HURON
LAKE MICHIGAN
Saginaw Bay
INDIANA
OHIO
Lake Erie
Michigan Weather Service
In co-operation with the U. S. Signal Service
Precipitation Chart
Annual Normal
13 Years Observations
Scale of Shades
Over 38

The annual rainfall for the year 1889 is the lightest on the records of the service, the amount being 9.03 inches below the normal, and in some localities of the state there was a deficiency of over 14 inches.

From the records it would appear that the rainfall for the year has been on the decrease for the past four years and should now be again on the rise, as this year—1890—will undoubtedly give a much larger annual rainfall than for the past three years.

This paper closes the months of rainfall in Michigan, and although the chart will in the coming years need revision, as there are now so many more available records to compute from that it will necessarily change slightly the lines as laid down on the charts, yet the material points will not be greatly changed and these charts should carry with them a valuable lesson relative to the rainfall in a state which is peculiarly situated because of the climatic effects of the great inland seas which almost surround it.

PHOTOGRAPH OF THE LAKE GERVAIS TORNADO FUNNEL.

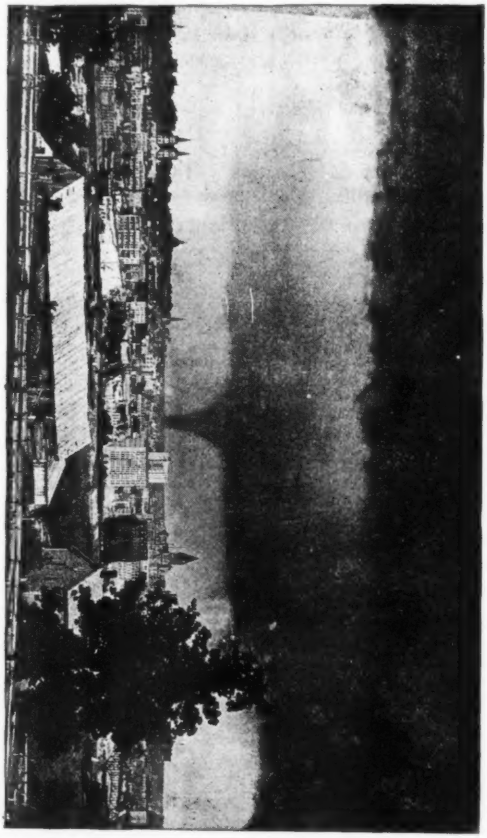
By the Editors.

The photograph of the funnel of the Lake Gervais tornado, which we reproduce in this number, was taken on July 13, 1890, by Mr. William T. Koester and published by Messrs Fredricks & Koester of St. Paul, who have kindly given us permission to reproduce it. It is, as Mr. Koester informs us, the result of a "chance shot" taken at about 5 P. M. from the west bluff of St. Paul, where this photographer happened at that time to be occupied in taking views. The point of observation was at the corner of Cherokee avenue and Ohio street. The point where the funnel touched the earth was, by the county map, full six miles away, in a direction a little east of north.

A photograph of a tornado funnel is of so much interest that we have taken some pains to assure ourselves both of the authenticity of this one and also that the plate had not been "touched up" or made over, so that the print is an actual copy of the funnel. For this purpose we consulted Mr. A. L. Colton, an excellent amateur photographer, entirely unbiased, well known to the writer, at present teacher of physics and chem-

istry in the St. Paul High School. Mr. Colton conversed with Mr. Koester and also informed himself as to the original plate. As a result he wrote the editors as follows:

"He (Mr. Koester) tells me that as he was returning from a viewing trip in West St. Paul he saw the tornado forming and



hastily set up the camera, adjusting the focus by extending the bellows to a certain point on the bed, which is quite practicable when one is thoroughly familiar with his instrument. He says his brother was with him. Orders for the prints came in so rapidly that in order to supply the demand he had to multiply

the negatives by first making a positive by contact, like a lantern-slide, and then a half dozen negatives from that. To make the positive, the original negative was placed over a dry plate in the holder, face to face, and exposed in a camera, the light being reflected into the lens by a large piece of blotting paper; and the negative copies were made in the same way. The unsatisfactory part is that the original negative cannot now be found, and Mr. Koester thinks somebody has broken it and does not like to own it.

"Thursday evening.—I called on Mr. Koester again to-day. He declares positively that no *retouching* has been done to the negative and no hand work except spotting out a small spot and a scratch in the clouds at the left, plainly seen in the print. The chemicals were so manipulated as to increase the contrast in the duplicate negatives. At both visits I examined one of them very carefully. It shows a slightly mottled appearance in the distant clouds. I suggested that it might be caused by the blotting paper reflector, which Mr. Koester says was not very clean, but he is inclined to attribute it to the kind of plate used for the duplicates, which he says sometimes gives a mottled appearance. This is plausible; plates do act that way sometimes. Some of the prints show this; others, including my own, do not; evidently from another negative. The mottling is unlike any retouching that I ever saw. The picture of the clouds at the top is undoubtedly a genuine photograph, likewise that of the city. The only question is whether the two have not been skilfully combined into one, with a manufactured funnel depending from the clouds. But I do not see how the funnel could be made to fit in so smoothly. The only suspicious feature of the picture itself is that along the lower edge of the dark cloud, extending from the funnel to the left, is a mottled appearance which looks a little like a bungling attempt to conceal, by retouching, the line of junction, and this line of junction, if it is such, is faintly continued to the end of the picture, as I see by looking at my print. To the right of the funnel this nowhere appears. I think if deception of this sort had been resorted to it would have appeared there also. Mr. Koester had observed this, but had no theory to account for it.

"On the whole, I am strongly inclined to believe in the authenticity of the photograph, though not beyond the possibility of a doubt. The doubtful features are: 1. The disappearance of the original negative. 2. The retouched appearance of

the line just described. 3. The signal service observer, Mr. Lyons, on whom I called this afternoon, was watching the progress of the storm from a point two miles further south and did not see the funnel descend, though his point of observation may not have been as good. Mr. Koester says the funnel descended three times."

It is only proper to add to this the following letter from the photographers who took the picture and have put it on sale:

"DEAR SIRS:—We take pleasure in granting you permission to reproduce in the AMERICAN METEOROLOGICAL JOURNAL our photograph of the tornado at Lake Gervais, July 13. We guarantee its genuinenes as a direct photograph of the phenomenon.

Very respectfully yours,

FREDRICKS & KOESTER.

Mr. Lyons' negative testimony would hardly be conclusive as to the presence of the funnel; negative testimony is never so conclusive as positive. The funnel was described by many, and in some cases minute details were given.

We clip the following accounts from the newspapers of the two cities from which the funnel might have been seen:

The *Pioneer-Press*, of St. Paul, says:

From the higher parts of St. Paul fronting north the storm was seen distinctly as it formed. A *Pioneer-Press* reporter stood on A. L. Larpenteur's lawn at 3:30, and looking northward along the line of Dale street was able to watch the formation of the storm center, which later worked such deadly havoc. The clouds were seen to gather from all points of the compass and were driven by the air currents to a point apparently some six miles north of the city. Here they centered and gathered into a dense, black mass, the diameter of which continued to be enlarged by the addition of large masses of vapor. Even at that distance the cloud was seen to be in rapid circular motion, and plainly in the center was seen a dark pendant funnel-shaped cloud. Around this, rapidly moving in a circle, was a great body of scud and mist. Gradually the whole body moved off in a north-easterly direction, the north-western side of the cloud being sharply cut off, while the north-eastern side was ragged and torn. At times the dark funnel was lost to view by driving mist or rain, and by 4:30 the entire cloud was obscured and lost sight of by a dense rainfall.

The strange appearance of the sky was noticed by hundreds of people in St. Paul, and many feared that a tornado was about

to sweep down upon the city. The crowd at the ball game at Athletic park on the West Side noticed the peculiar aspect of the storm as soon as it gathered, and naturally became apprehensive of danger. Hundreds rushed to the fence on the north side of the grand stand and watched the progress of the storm as it traveled rapidly northeast of the city. The dense black clouds, ominous in their threatening attitude, assumed the appearance of an immense funnel revolving inward and outward with great rapidity. Suddenly the funnel seemed to drop out of sight and become dissipated by contact with the earth, and a second later another funnel formed further east and began to move quickly in an easterly direction, finally disappearing from view. The crowd's anxiety ceased and the game went on to its conclusion, the spectators being unaware that any damage had been done to life or property.

The passengers on the train which left White Bear at 4:55 P. M. for St. Paul had a thrilling experience. When the train was approaching Gladstone the tornado was observed on a hill about a quarter of a mile distant, moving at a rapid rate, apparently after the train. The passengers were alarmed and crowded the platforms to watch the sight. Charles Stewart, bookkeeper for R. M. Newport & Son, who was on the train, says that at first the clouds appeared like spirals rapidly turning and revolving around one another, and then they became densely black and assumed the shape of a funnel. It was following the train to all appearances, and as the wind was blowing the same way the passengers were greatly alarmed. The engineer put on more steam and soon the train drew away from it.

The Minneapolis *Tribune* gives a more detailed, and, in many ways, a highly instructive account of the formation of the funnel. It says:

Yesterday's tornado was viewed by a company of gentlemen from the Hotel Clinton, fourth avenue, south, and Grant street, much after the fashion generals have sometimes adopted of watching a battle from some prominent elevation out of harm's way. They had accessories in the way of a field glass and a camera, and when the twirler was at its closest point to Minneapolis a photograph was taken of it, which will be ready to be shown this morning.* The observation was almost by chance.

*We have been able to learn nothing of the photograph.—EDITORS.

The sultriness of the weather during the forenoon and early afternoon suggested the possibility of a cyclone, and when at about 4 o'clock the heavy and dark rain clouds began to gather to the north of the city and a storm seemed to be impending, J. F. Hogle, of the Hartford Life and Annuity Company, who lives with his family at the Clinton, and E. B. Crabbe, of Hale, Thomas & Co., who lives at the same place, together with several others, went to a north third-story window out of curiosity to see what would be the result. They had not very long to wait. The storm cloud back of the heavy black rim which encircled its front was of a sickly copperish hue, and in its center an unusual commotion manifested itself. The eastern edge of the cloud was on the horizon at a point directly across the flour-milling district from them, and the western edge over the center of the high school building, the center, in the customary semi-circular form, being well advanced toward Minneapolis.

A mass of small black clouds gathered on the face of the storm cloud, and as they gathered it could be seen there was a great atmospheric disturbance. They rolled and tumbled one over another, and occasionally the whole mass would suddenly and swiftly drop toward the earth, but, recovering itself in a moment, regain its place in mid-air. Up to this time there had been no funnel formation, and nothing to suggest that a tornado was at hand. About five minutes after 4 o'clock, Mr. Hogle thinks, the black mass was suddenly elongated and came to the ground in the neighborhood of the stockyards. It was located, from where the gentlemen were standing in the hotel, immediately over the top of the Central High School tower. The funnel was perfect and the rapid whirling motion was distinctly visible. From the main body black clouds were continually shooting out and then retiring, and in addition to the rotation there was a movement of air up and down on the edge of the tornado, which carried with it the small clouds that had been thrown off from the storm center.

The point of the funnel did not remain on the earth, Mr. Hogle thinks, longer than a minute or two. Then it suddenly drew itself up until there was only the heavy mass of angry dark clouds. These, too, almost entirely disappeared, and the gentlemen, who by this time had got to the roof of the Hotel Clinton, thought they had seen the last of them. Not so, however.

In about five minutes they saw the funnel forming again,

this time nearer to Minneapolis and at a point in the sky between the new buildings of the Northwestern Guarantee Loan Company and the New York Life Insurance Company, from where they were standing. It repeated itself this time, forming gradually in the air, amid great commotion and dropping to the earth, where it remained but for a moment, as before. When the funnel scattered a second time it did not appear for perhaps ten or twelve minutes. At about 4.15 P. M. the clouds were seen coming together again, this time over the top of the B elevator of the Milwaukee road, below the Milwaukee depot. All the time, Mr. Hogle says, the storm was from ten to fifteen miles from Minneapolis as near as he can estimate, and gradually drawing nearer to the city. It moved rapidly eastward and slightly southward, covering the distance between the point where it was first noticed and the point over the elevator, which marked the scene of the fatality in St. Paul, in about twenty-five minutes. The distance could not have been less than forty miles.

The third formation was more portentous by far than either of the preceding ones, in the ratio of fully fifty to one, and as the funnel dropped to the ground for the third time it was an imposing sight. Its top was apparently more than a mile in circumference and it tapered gradually from this to the smallest possible proportions at the lower end. Says Mr. Hogle: "This time we could see that the effects would be terrible. The cyclone remained on the ground fully ten minutes, increasing in size and velocity all the while and moving exceedingly slow. In ten minutes it did not move over a distance greater than half the length of the big B elevator, as we saw it. This probably meant several miles. At times it seemed almost stationary, and when at last it lifted itself and finally disappeared it was 4.35 o'clock. I caught a good photograph of it while it was at its height, and have in the photograph a flash of lightning that went across the face of the tornado just at this time."

ERRATUM.—In the article on "Temperature in Anticyclones and Cyclones," printed in the JOURNAL for December, 1890, the temperature for the Low area, at 3,500 meters (table on page 390) should read — 9.1, not — 0.1.

OBSERVATIONS AND STUDIES ON MT. WASHINGTON.

BY PROFESSOR H. A. HAZEN.

(CONCLUDED.)

Mount Washington Dew-Point.—The sling psychrometer was observed at every available opportunity during the day hours from 5 A. M. to 8 P. M. From these observations I have computed the dew-point and the mean results are here given.

MEAN HOURLY DEW-POINT.

5 A.M.	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
42.9°	42.5°	42.0°	*41.6°*	43.2°	44.1°	45.0°	45.4°	45.7°	45.8°	45.8°	45.8°	*45.9°*	*45.9°*	45.7°	45.6°

WASHINGTON, D. C., DEC., 1888.

7A.M.	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
23.3°	*23.2°*	23.5°	23.8°	*24.2°*	23.8°	23.5°	23.1°	23.1°	22.8°	*22.6°*	22.9°	23.4°	23.8°	23.9°	24.0°	*24.1°*

I have added the mean hourly dew-point at Washington, D. C., during December, 1888. It will be seen that the latter seems to have a double oscillation, but it is probable that the 11 A. M. maximum is altogether too prominent in this month. The Mt. Washington results, however, are entirely different; here there is a minimum at 8 A. M., after which there is a steady rise until 6 P. M., when there is a slight drop. The 8 A. M. minimum seems to be a true phenomenon, but observations for a single month are not sufficient to establish the law. It was due in large measure to several remarkable periods of dryness. These dry spells were looked for, hours at a time, whenever there was no fog, but they were never found after 9 or 10 A. M. It should be noted that the summit was covered with cloud more than half the time and this must have disarranged the diurnal change which would have been noted in the free air. The maximum point probably was brought about, in part at least, by the flow of warm, saturated air deflected upward by the mountain side. The maximum temperature, however, occurred about 1 P. M., so this explanation is not wholly satisfactory.

There is a constancy in the dew-point which compares with that already discovered at sea-level. There are a few most remarkable exceptions and most of these occurred in the early morning hours. While a single month's observations would hardly suffice to establish a law, yet from the frequent absence of clouds in these earlier hours there seems to be a well-defined tendency to a diminution of the dew point at this time. Three of these instances on July 22, August 6 and August 21 are given in Table III.

TABLE III.—REMARKABLE DRY PERIODS.

July 22, 1889.				August 6.				August 21.				
Time, A. M.	Dry.	D. P.	R. H.	Time, A. M.	Dry.	D. P.	R. H.	Time, A. M.	Dry.	D. P.	R. H.	Weather.
5.45	45.0	35	69	5.36	35.4	35	100	5.45	44.9	30	57	Cloudy, no fog.
6.00	47.4	29	49	5.40	35.4	33	91	5.47	45.0	29	55	
6.03	47.0	30	52	5.52	37.0	20	50	5.49	45.4	29	55	
6.05	44.3	38	81	5.54	35.4	31	86	5.53	45.3	23	42	
6.20	44.4	31	61	5.55	36.5	24	62	5.55	45.1	26	47	
6.21	47.6	29	49	5.59	36.0	27	71	6.02	45.8	29	51	
6.23	44.5	37	78	6.00	35.1	32	91	6.05	44.7	31	60	
6.27	47.5	27	45	6.03	35.7	28	77	6.08	44.8	31	60	
6.29	47.6	27	45	6.22	36.2	24	62	6.17	45.7	28	53	
6.31	45.2	35	69	6.24	35.8	29	77	6.18	45.8	27	48	
6.33	45.2	35	69	6.25	36.2	26	69	6.19	45.2	28	58	
6.36	44.7	37	75	7.40	38.6	23	55	6.21	45.7	26	45	
6.39	45.8	33	62	8.16	41.4	20	43	6.36	45.0	29	55	
7.16	51.8	11	18	8.18	41.1	20	43	6.39	45.5	28	53	Light rain.
7.19	50.8	17	26	8.21	41.0	18	40	7.34	45.6	20	37	Light rain.
7.54	53.0	10	18	8.23	41.2	17	38	7.35	45.7	18	32	
8.16	51.8	14	22	8.52	41.5	20	43	7.37	45.7	18	32	Light rain.
8.19	51.2	26	38	10.56	48.6	42	76	7.39	45.8	18	32	Light rain.
8.23	49.9	47	90					7.41	46.0	18	32	Light rain
8.26	50.0	46	87					7.42	45.4	18	34	
8.41	52.0	48	87					7.43	46.2	21	36	
								7.46	46.0	24	42	Light rain.
								7.47	46.0	19	33	
								7.50	45.4	22	40	Light rain.
								7.51	45.0	22	40	Heavy rain.
								7.52	43.8	26	49	
								7.53	43.0	29	58	Rain.

The change in the dew-point during these periods was remarkable. It was not a steady drop, but there was a continual rise and fall, especially in the earlier part. For example, the relative humidity at 6.21 A. M., July 22 was 49 per cent., at 6.23 it was 78 per cent. and at 6.27 it was 45 per cent. While there was no fog on the summit at this time, yet there were probably quantities of invisible vapor rapidly passing over during the general dry period. The wind velocity in the first two cases was nearly inappreciable, about 5 miles per hour, while in the last case it was 23. The most remarkable occurernce was the morning of my departure. At 5.45 the air was very dry, relative humidity, 57 per cent. This dryness continued and even increased till 7.41 and this increase during the latter part of the time occurred during a light rain which occurred at 6.39. At this time the relative humidity was 53 per cent., while at 7.41 it was 32 per

cent., though light rain had fallen for an hour. It was necessary to rig up a rubber coat in the open air to prevent the rain from striking the dry thermometer. At 7.53 the relative humidity had increased to 58 per cent and quite heavy rain was falling. For the first time in six weeks we had rain on the summit without dense fog. These facts are very instructive. It would seem as though these dry periods must be due to an effect from the free air on a plane with the summit or from a descent of air from a higher level, or from some other cause not distinctly understood. It seems quite plain that no ascending current of warm, moist air is needed to produce rain at the summit. There had been no rain on the side of the mountain as we descended it an hour later.

Cloud Formation.—Particular attention was paid to the phenomena of clouds at all hours; these were readily observed except when the peak was enveloped in fog and then an observation could only be made by walking two or three miles down the side of the mountain. When the peak was not covered with a dense pallium from the progress of a general and widespread storm, there were cloud forms which may be divided into three characteristic and rather persistent classes. First. The "cap." This barely touched the peak or just rested on its top as the wind rapidly carried it away. Second. The "hood," or a cloud covering the summit entirely to a depth of 1,000 or 2,000 feet and extending out three to four miles on all sides. Third. The "curtain" or a curtain-like cloud or patches of cloud which surround the peak in a complete circle without touching it. The cloud did not always reach the peak. It was formed at 10 A. M., or later, and the distance from the peak was usually more than ten miles. The thickness or darkness of the curtain was much deeper on the windward side than on the leeward. In one case while standing on the observatory tower making a psychrometer reading I noticed a thickening in this curtain right in the teeth of the wind; in a few seconds a detached cloud appeared to come with great velocity to the peak and there was a deluge of rain before I could leave the tower, In this case the rain was but momentary. These cloud forms were of the cumulus or cumulo-stratus variety and could be best observed when the peak was in cloud, by walking out from under the edge of it. The appearance was markedly as though there were a peculiar local effect producing the clouds around the mountain. Frequently in going down when the summit was in cloud, the top of

Jefferson could be distinctly seen while just a bit of a "cap" would be on Adams, 59 feet higher than the former. The edge of either cloud "cap" or "hood" was quite often sharply defined and one would need to walk only a few feet to emerge from dense fog into sunshine and a clear, blue sky. It has been the well-nigh universal opinion of travelers, and this view has also entered some scientific works, that the rocks and soil on the summits of our mountains are cooler than the air blowing over them; in consequence the warmer air coming up the side of the mountain has its moisture condensed and this gives the persistent cloud forms. There are serious objections to this view, however. First. Careful observations of the rocks and soil showed that their temperature was above that of the air all day and all night. There are only two exceptions to this rule and in both of these there was no fog or cloud on the summit. On two mornings before sunrise I found the rocks and grass about 1° lower than the air, and it was very easy to see the reason for this; the sky had been perfectly clear during most of the night and the intense radiation into the sky had cooled the rocks below the air. As there was no cloud this very fact would disprove the hypothesis. A second reason for the opinion that the cool summit does not produce the prevailing clouds in that region is the great hight at which they occur. It was practically impossible to determine the hight of the cloud with means at my disposal but it must often have been over 1,000 feet. It was often quite easy to distinguish between the current coming up over the edge of the mountain and that flowing freely above it, from the fact that the lower cloud and fog were blowing more rapidly than that 50 feet above it. It is manifestly impossible to conceive that a current of moist air blowing at the rate of 30 to 60 and even more miles per hour across the peak could have more than a few feet in thickness cooled even a perceptible amount by the rocks even, though they were two or three degrees cooler.

Third. The horizontal extension of the two first forms of cloud preclude the possibility of the cooler mountain producing them.

Fourth. The third form of cloud "curtain" could not be formed in this way at all but really is a positive disproof of that view.

Another view advanced by some physicists, namely, that the air blowing upon the side of the mountain is compressed and as

it rises on the windward side there is an expansion and the cooling in consequence of this produces the condensation of vapor necessary for the cloud. A serious objection to this view is that it calls for an uprising current of far greater power and extent than can possibly occur in this region. As we have already seen the topography of the mountain is such that the great mass of air coming up the side of the presidential range divides and passes off on either side of the summit cone. All the objections just advanced against the former view hold in the present case except the first. These phenomena are certainly of the deepest interest and we may hope that a more extended study of these forms may be made. Mountain climbers in this region might assist in this study by carefully recording the extent of the cloud and its characteristics as they approach the peak. The most satisfactory way would be to have the observers stationed at points three to ten miles from the mountain and on all sides as well as the summit, these to carefully record at stated intervals the cloud appearance. If there could be telephonic connection it would be more satisfactory. A word may be added as to the method of measuring the temperature of the rocks. Several plans were adopted and they all gave practically the same result. The easiest method was to put the thermometer in a little pool of water on the rock. A small hole was bored in the top of a plank and filled with mercury; the temperature of the mercury was then measured. There were little patches of sand here and there among the rocks and the temperature was taken by pushing it in nearly a quarter of an inch nearly horizontally, also the temperature of tufts of grass and moss were taken.

Drying of Planks.—Intimately associated with the cloud phenomena was an appearance which attracted a great deal of attention from visitors, namely, the drying of the summit planks and walks while the air was yet full of fog and apparently perfectly saturated. By suggestion of Professor Newcomb I poured water so as to make little patches on the planks during one of these periods, and then the gradual disappearance of the definite patches could easily be watched. The explanation of the apparent anomaly is not entirely simple. It was found that the plank was invariably much warmer than the air under these conditions, and proportionately much warmer than when they were covered with water in a rain-storm. This

increased temperature, as will be seen later in one case, amounted to 12°. It also seemed probable that tha air was not entirely saturated, though apparently full of fog, for when there appeared a momentary clear space in the fog an immediate observation of the sling psychrometer showed the wet lower than the dry. This could not be learned in the fog, for that converted the dry bulb into a wet one at once. It is suggested that the air an inch or two above the plank may be just a little warmer from the heat imparted by the plank and as a result it is not quite saturated, but absorbs the moisture and dries the plank. The plank itself, however, may cause the heated moisture in contact with itself to rise into the cooler air and thus become itself dry. To test this question and to find some explanation for this marked heating, a free black bulb thermometer was laid upon a surface of black cloth, which was placed upon the plank; the temperature of the plank was also determined by the thermometer immersed in mercury as already described. The air temperature was obtained by the sling psychrometer. As there was a dense fog during all these readings the air and dew-point temperatures were identical.

TABLE IV.—*Temperature of black bulb, planks and air.*

Aug. 15, 1889. A. M.			
Time.	Black.	Plank.	Air.
9.35	61.0	58.3	....
37	61.4	58.4	....
38	63.0	58.7	....
39	62.1	59.0	51.2
40	60.1	58.5	50.4
42	59.3	58.0	50.6

Aug. 15, 1889. A. M.			
Time.	Black.	Plank.	Air.
9.43	58.8	57.9	50.8
44	59.1	57.8	50.5
45	60.0	57.9	50.3
46	59.5	58.0	50.9
48	61.2	57.8	50.4
49	62.4	58.4	51.0

Aug. 15. A. M.			
Time.	Black.	Plank.	Air.
9.50	62.6	58.5	51.0
9.51	62.0	58.7	51.0
11.25	54.8	55.3	50.4
11.26	54.0	54.9	50.3
11.28	53.0	54.7	50.3
Mean, A. M.	59.7	58.3	50.7

Aug. 15. P.M.			
Time.	Black.	Plank.	Air.
14. 4	71.6	63.0	52.0
6	72.5	63.8	50.8
8	72.0	62.4	51.4
11	70.9	62.2	51.3
13	75.3	62.8	52.0
14	78.0	63.3	51.4

AUG. 15. P. M.

Time.	Black.	Plank.	Air.
14.15	79.5	64.0	52.4
16	83.0	64.4	52.0
17	86.0	65.1	....
18	88.0	65.7	....
19	89.0	66.5	52.9
20	90.5	67.7	....
Mean, P. M.	79.7	64.2	51.8

AUG. 17. A. M.

Time.	Black.	Plank.	Air.
9.59	64.0	52.3	41.3
10. 1	61.4	52.0	41.6
10. 3	58.3	51.8	42.0
10. 4	55.9	51.0	41.3
10.13	51.6	48.0	....
Mean.	58.2	51.0	41.4

These results in Table IV show a remarkable heating effect of the sun at the summit even through dense fog. On August 15 the free black bulb temperature rose almost steadily from 9:35 A. M. to 2:20 P. M. nearly 30°, in the same time the plank temperature rose nearly 10°, while the air temperature rose only a little over a degree. The sun would seem to have a marked power of penetrating through fog yet without heating it, though this diminished heating of the air may be partially accounted for if we suppose that the free air on the peak was continually renewed by the free air to the westward, which was naturally cooler than it. It should be noted, however, that we must accept this view with caution, for it partially contradicts the opinion of some, as already brought out, that the air on the peak comes from below and is slightly warmer than the peak air. Many more observations will be needed under varying conditions of wind, density of fog, etc., before the true law of heating by the sun can be settled.

Wind and Storm Movement.—It is of great importance that we determine definitely the relation between the direction and velocity of the summit wind and the direction and velocity of storm progression. If the center of the storm movement is not far from the summit of Mount Washington, as is believed by some, and this progression is a drift in the upper air currents, then we ought to obtain some idea of the drift by observations of the wind at the summit. Careful observations showed that, with only two exceptions, the clouds just above the peak and to all other hights move with the summit wind. Observations showed also that clouds 1,000 or 2,000 feet below summit, or from the bottom of the "hood," had the same general tendency, though the latter were affected by local irregularities. In general it is safe to consider that the atmos-

phere in all this region, both at a great height above the peak, and just below it, has a motion with the summit wind, or we may say this is the general drift of the atmosphere. Let us take from the synoptic charts the mean direction and velocity of all the storms and high areas during this period and compare with the wind on the summit.

TABLE V—*Mean direction and velocity of summit wind and storm progression.*

Storm I.					Storm II.				
	Mean.					Mean.			
Date.	Wind.		Storm.		Date.	Wind.		Storm.	
July, 1889.	Dir.	Vel.	Dir.	Vel.		Dir.	Vel.	Dir.	Vel.
14_2—15_1	NW	35	W	30	18_1—18_2	W	11	NW	20
15_1—15_2	NW	26	WSW	26	18_2—19_1	SW	12	WSW	22
15_2—16_1	NW	44	SW	55	19_1—19_2	S	22	NW	22
16_1—16_2	W	55	E	13	19_2—20_1	S	33	SW	16
16_2—17_1	NW	45		0	20_1—20_2	W	32	WNW	11
17_1—17_2	NE	16	NE	25	20_2—21_1	NW	36	SW	21
					21_1—21_2	NW	21	W	20
Storm III.					**Storm IV.**				
22_1—22_2	SW	8	W	28	29_1—29_2	S	49	WSW	12
22_2—23_1	SW	18	W	10	29_2—30_1	W	34	SW	31
23_1—23_2	W	39	SW	27					
Storm V.					**High Area.**				
Aug., 1889.									
1_2—2_1	W	41	W	23	24_2—25_1	W	49	NW	16
2_1—2_2	W	22	W	12	25_1—25_2	NW	50	W	34
2_2—3_1	SW	37	WSW	10	25_2—26_1	NW	30	S	18
3_1—3_2	W	37	SW	9	26_1—26_2	SW	8	SW	33
3_2—4_1	W	40	SW	12					
4_1—4_2	W	33	SW	14					

The evidence from these figures is very strong that storm progression in neither direction nor velocity is the same as that of the wind at the summit, nor, we may say also, is it the same as that of the drift. It would seem possible to settle this exceedingly important question by observations on more or less isolated peaks in the same region at hights of 3,000 to 6,000 feet. It is of great interest to determine the hight at which the usual circulation of the wind at sea level in our storms terminates or

gives way to the general current from the west. Also by careful observation both of the wind and clouds at these different hights the exact direction and, as far as possible, the velocity of the drift of the atmosphere; when this is definitely determined we can readily compare the direction and velocity of storm and high area progression with it.

Thunder-storms.—There were several severe thunder-storms, two being of special interest as they were sufficiently widespread to extend from the Glen House to Fabyans, or else their motion was between those stations and over Mt. Washington. The first was on July 29. The barograph trace shows a marked rise at all three stations, but somewhat earlier at Mt. Washington. The trace has also a rapid fall immediately succeeding the rise. The second storm was on August 10. In this case all three curves show a marked rise, but the summit rise is a little later than that at Fabyans and Glen House. These curves are intensely interesting and show that the cause of this rise in pressure in our thunder-storms must be in the atmosphere at a height above 6,300 feet. The rise on July 29 was nearly the same at all three stations, but on August 10 it was the greatest at Fabyans, less at the Glen House and least at the summit. It would seem as though careful observations of this phenomenon in a mountain region with barographs and sling psychrometers at a dozen or more stations would shed a great deal of light upon its mechanism now so difficult to understand.

Aurora.—This phenomenon occurred frequently, and this was remarkable since it was at a minimum period. It seems quite probable that, in the summer time at least, every storm of any severity is preceded by an aurora at this high altitude. This fact would seem to show the great importance of observations of atmospheric electricity at the summit. The telephone running to the Glen House was observed day after day, and it had a continual sputtering and spitting such as I have noticed only in violent thunder-storms at sea-level. On one occasion in going down the road to the Glen House I noticed not far from mile post V lightning playing in a cloud within a few feet but without thunder; it was more like the phenomenon called heat lightning except that it was right at hand. On several nights it was found that while the physical condition was far above normal it was impossible to sleep. This was remarked upon by several who have spent many seasons at this point, and it was noted that all laid the lack of a desire to sleep to the excitement caused

by intense electric action. On these occasions severe thunderstorms frequently followed the wakefulness. Ordinarily the ability and desire to sleep was much stronger than at sea level. At one time while sitting quietly I found my pulse at 104, though I had found it 70 again and again. There had been no physical exertion preceding as this was in the early morning.

Optical Phenomena.—The continual fog gave excellent opportunity for observing at times various optical effects. The most common were the "anthelia." These surrounded the natural sized shadow of the observer cast upon a bank of cloud at a distance of several hundred feet in a direction away from the sun. This shadow was surrounded by beautiful circles having the prismatic colors. On one occasion four distinct circles were seen. It was seen to best advantage just at sunrise by standing on the observatory tower with back to the sun and watching the fog as it drifted past. It could not be well seen if the fog enveloped the observer. The rings were probably formed by diffraction in minute mist particles.

Coronae and glorys were also seen about sun and moon but much to the better advantage around the moon. These were seen of course between the observer and the moon. The glorys seemed to be formed on the passage of the light through minute mist particles, for they would disappear and appear as mist or fog floated over the moon. The coronae remained more permanently and were farther away, caused probably by the passage of the light through ice spiculae or frost particles formed at a great hight.

Spectre of the Brocken—This was seen twice as cast by the sun, and repeatedly by many visitors, as cast by a lamp. It was only visible when fog enveloped the observer or was very near. It was a gigantic appearing shadow cast by the sun into the fog. The observers' body cut off from the fog a prismatic shaped body of light. A section of this shell, as we may call it taken at right angles to the line from the sun, continued on through the observer, would have a contour exactly that of the observer. The explanation of this phenomenon has been hedged about with great mystery and uncertainty. It is believed by some that the shadow is not enlarged, but that the eye is deceived and thinks the object much farther away than it really is. This is far from satisfactory, however. The principal error in theories regarding this appearance has occurred from confusing the shadow of the

observer with its surrounding anthelia, as cast upon a distinct cloud bank with the true Brocken spectre which is totally different. The former phenomenon has been seen thousands of times and described as of the natural size; there certainly has been and can be no deception in that case. On the other hand the Brocken spectre has been seen hundreds of times, and by just as good observers, and they have declared that the image was enlarged. The explanation seems quite simple. If we hold a sphere in the sun's rays at the time of a fog or dense haze there will appear to one standing at one side, a dark band passing out away from the sphere and beginning at it. This band is quite distinct, and, if one looks from a point near the sphere, will appear to converge from the perspective effect. This appearance is very frequently seen in what is called "sun drawing water," in which rays appear to diverge from the sun and gradually expand. In this case we are looking from a point away from the sun, and the perspective effect makes the farther part of the shadow narrower than that nearer the observer. This appearance is beautifully shown on foggy mornings when the sun is breaking through. The branches and leaves of trees cast shadows upon the fog and these appear like straight lines emanating from the branches. The same can be seen on looking at shadows cast by an arc electric light on the street upon dust or fog. In this case a shadow is seen starting from any object near the light, for example a foot rest on the pole or the rod holding the bottom of the light, and extending out from the pole fifty feet or more. This shadow starts smaller at the pole and gradually widens because of a slight magnification from the nearness of the light. The object may be one-half inch across and the end of the shadow will appear a foot across. It is plain, however, that this magnification has nothing to do with the real shadow which appears to extend out from the light. Let us return to our sphere and its shadow. If this sphere were lifted up the shadow or band as viewed from one side, would go up and *vice versa*. Suppose the head of the observer were placed on the side of the sphere away from the sun and looking in the direction of the band, or into the centre of the shell which appears as the band when one stands on one side, he would see the inside of the cylindrical shadow cast on fog particles, first just at his head and then farther and farther away. If he stood on one side looking at this shell it would appear perhaps one hundred or more feet in length, the last fog particle receiving the

visible shadow being that distance from the sphere; when he looks into the shell he sees the same shadow upon the same fog particle one hundred feet away. Let us take away the sphere and allow the sun to cast the shadow of the observer upon fog particles. Here he sees, as before, a shadow disappearing in the distance, but now, instead of being uniform and a cylinder, it is of regular shape; the arm, if stretched out, casts its shell of shadow and when it is moved up or down this long shell disappearing in the distance rises and falls throughout its length, just as in the case we have already noted with the sphere. The phenomenon is certainly very interesting, and everyone who spends a night in a dense fog should make it a point to view it by allowing a light placed at the back to cast a shadow into the fog.

October 18, 1890.

ACCESSORY PHENOMENA OF CYCLONES.

By H. Faye,
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(CONCLUDED.)

The Prediction of Storms and Tornadoes.—To be in condition to indicate at the appearance of a storm the region menaced by the invasion of tornadoes, the approximate trajectory must first be traced from the earliest observations made, as an astronomer calculates the immense trajectory of a comet, by the little arc which it passes over in the first few days. But the first observations will give nothing useful unless there is, *a priori*, a distinct idea of the nature of its curves. This first idea, as regards storms, is given us in Redfield's Laws.

These considerations bring to mind the enterprise which has struck me most among those of the century, and of which I have spoken many times in France.* The noble enterprise of the *N. Y. Herald* has been abandoned, doubtless on account of some mistakes, but I am led to impute a large part of these errors to the imperfect manner in which the trajectories of cyclones upon synoptic charts were traced then, as now, under the inspiration of the prevailing theories.

For example, if it is desired to utilize the isobars, the first condition is not to confound the domain proper of the storm, where causes foreign to the phenomena are in great part to be

*See my remarks *sur les grand fleaux de la nature*, "l'Annuaire du Bureau des Longitudes," 1884.

ignored, with the exterior zone in which the influence of temperature is limited to modifying the preëxisting pressures, and the previous condition of the atmosphere. The second is to keep an account of the progressive deformations which the system of isobars undergoes with time.

At sea where the wind arrows play necessarily a principal part (for the data for tracing the isobars are lacking), the prevailing ideas give a false notion of the system of winds in a cyclone, so that the position of the center remains partly undetermined. This gives rise to singular tracings, capricious undulations, knots, dislocations, etc.

FIGURE 5.

Figure 5 is, for example, the diagram of a tropical cyclone, according to the hypothesis of the spiral indraft. I take it from the *Journal of the Scottish Meteorological Society*, 3rd series, Nov. 6, 1888.

The wind arrows inflect a little ahead without forming a real gyration around the central calm. In the rear they progress almost straight towards this calm. If cyclones were thus constituted how should we discover and mark the center around this collection of arbitrary curves? We find then curves like the following taken from the collection before mentioned in the vicinity of the Reunion and Mauritius.

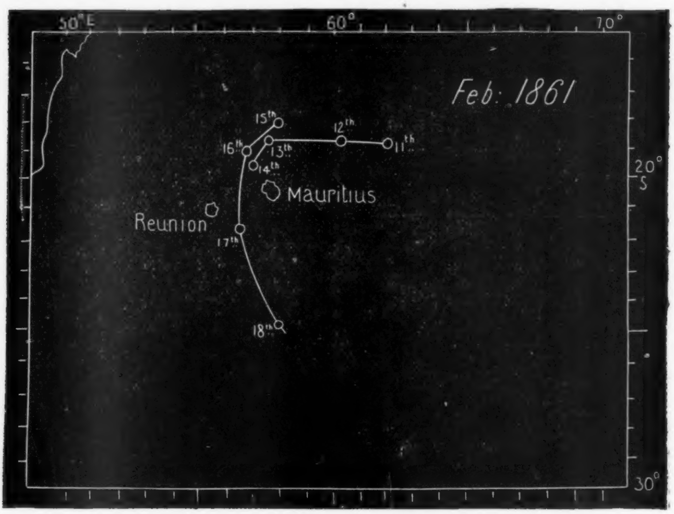

FIGURE 6.

Such mistakes are fortunately not to be feared in the United States, for I find in the *Pilot Charts of the North Atlantic Ocean* a typical figure of a tropical cyclone which has no resemblance to the preceding.

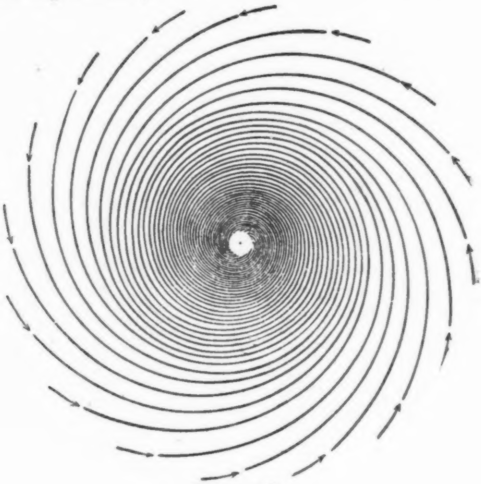

FIGURE 7.

In this the wind circles with great velocity around a central calm, in the rear as well as in advance, and the center may be perfectly determined. It conforms almost exactly to cyclonic laws. The application of these rules to the preceding storm may be seen in the design of its trajectory according to commandant Bridet, captain of the port at *La Réunion* (and a special student of cyclones).

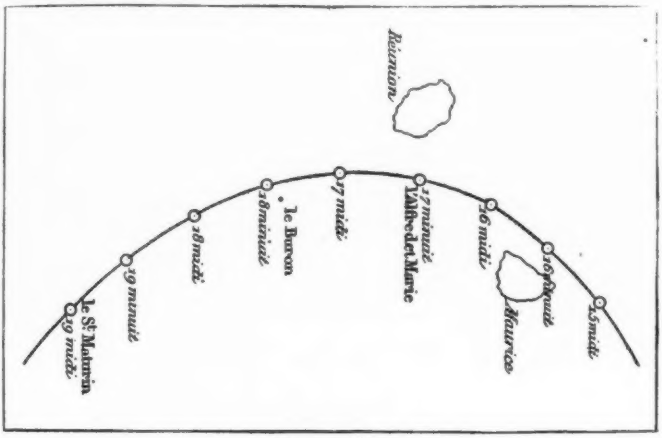

FIGURE 8.

This tracing presents no anomaly. The recurvature (normal for the season) takes place towards 22° of south latitude.*

This is not saying that the superior currents where cyclones originate are invariable in their course: but it is certain that these currents do not retrograde any more than our rivers flow back towards their source, that they never jump from one point to another, and that they never form into knots, etc. When such singularities are encountered upon synoptic charts, it shows that there is reason to require better documents or to operate in a more systematic manner.

The charts recently published by Mr. Finley, upon the trajectory of storms of the North Atlantic give, it is true, numerous examples of irregularity; but all together they are a striking demonstration of the great fact that the storms which traverse the United States, those which pass at large near the Bermudas or even near the Azores, are directed toward the coasts of the

* Bridet: *Ouragans de l'hemisphere australe*, 1876, p. 137.

north, center or south of Europe. Many of these are exhausted on the way, before reaching these coasts; there have been counted, however, in seventeen years, one hundred and forty-one which might have been announced to us by telegraph three or four days in advance. I think there would be still more if the trajectories wore studied from a purely cyclonic point of view.

This confidence in the regularity of trajectories is founded independently of all theories, first upon the works of Redfield, Reid, etc., for the Atlantic ocean, upon those of Piddington for the Indian ocean, upon those of Thom and Bridet for the other hemisphere, and upon those of their numerous successors. Everywhere, in every epoch, the trajectories which have been most completely studied have been presented under the well known form of parabolic curves having their first branch near the equator directed to the west, then to the north-west, their summit at 20° or 30° of north latitude (or south latitude); their second branch directed to the north-east (or south-east). "The Sailor's Hand-Book," recently published by Mr. Finley, shows that the trajectories of storms which are supposed to have begun in mid-Atlantic follow the second branch and progress nearly north-east, as well as those which have described the entire parabola, a fact which seems to me worthy of mention.

If we enter into details we will find, with P. Vines, who has made so profound a study of tropical storms (absolutely nothing distinguishes them from any other), that the summit of the parabola varies regularly in latitude, with the progress of the sun in declination. The same is true of the other hemisphere. It appears that these variations are in close relation with those of the thermal equator.

In spite of this general conformity between observations and the accepted laws, there are sometimes striking exceptions. This is the case with the storm in the Gulf of Aden (June, 1885), which caused the loss of the *Renard.* This storm has been studied in France by Admiral Cloue, former minister of the Navy, and in Germany by the Met. Bureau of the German Navy. These two investigators arrived at nearly the same trajectory. I called attention to the fact that this trajectory deviated sensibly from the regular path, at the same time that the diameter of the cyclone, instead of growing with time, was notably decreased. Another still more striking example was given by the cyclone of September, 1888, which nearly compromised at Havanna the reputation of P. Vines, because instead

of recurving according to the rule, it pursued its way towards the west across the Gulf of Mexico.

We must believe that the upper return currents, in the midst of which cyclones originate, are subjected at times to serious modifications which have not yet been studied, for there is no authority for attributing the change of route of these two cyclones to superficial accidents of the terrestrial globe. This is certainly a question which ought to receive careful examination, but the rare exceptions* cannot invalidate the rules which are verified every day in the two hemispheres.

It will not be going outside this subject to approach a question of which I have not yet spoken, that of anticyclones. Many meteorologists think that storms are arrested or deviated when they reach a region of high pressure, that is to say, a region where the barometer remains during some time at ten or twelve millimetres higher than the ordinary. To be in condition to announce the arrival of a storm from America in Europe, it would be necessary according to that, to know the distribution of high pressure along the whole path, which is impossible.

But high pressures are simple static phenomena like ordinary depressions. Each remains and disappears on the spot, or is disturbed little by little, without describing trajectories, on account of local influences. A cyclone passing over a "high" of a centimetre will lower the barometer a centimetre less than if the atmosphere was at its normal pressure; in passing over a "low" it will lower the barometer a centimetre more, and that is all. This super-position of effects due to different causes is verified in a striking manner by the daily barometric variations on the passage of a cyclone. This variation is effaced but little between the tropics except at the heart of the storm.

I shall permit myself then the expression of the opinion that the great enterprise of which I have just spoken might be undertaken again, with benefit, upon a new basis. Doubtless the service rendered to Europe would be without possible reci-

*This would be otherwise if the objections which Mr. Arthur Dutton made in the April (last) number of this Journal, to the rules of P. Vines, were well founded. Mr. Dutton cites numerous cyclones where trajectories have not recurved, like those which I have just mentioned. Mr. Finley's hurricane chart (the Sailor's Hand-Book), has reassured me on this point. However, it would be well to subject each of these cyclones to a new investigation. In studying these trajectories with more complete documents, in removing the chances of error introduced at times by the simultaneous existence of several cyclones, I should hope that most of these exceptions would come under the rule, like the astonishing trajectory of the cyclone of February, 1861, determined by Mr. Meldrum, and reported by Ralph Abercromby in his recent memoir.

procity, for it is a law of nature, comprised in Redfield's Laws, that Europe will never be struck before the United States, Boston before Philadelphia, nor the Island of Réunion before the Mauritius. But the announcement of these storms, if it were possible, as I believe, would be a benefit to all countries whose vessels furrow the Atlantic.

Conclusion.—At the time the laws of storms were discovered and clearly formulated nearly a half century ago, science found itself disarmed in the face of a phenomenon characterized by two movements at the same time, a violent gyration and a majestic movement of translation upon a geometrically determined trajectory. Astronomy and celestial mechanics had familiarized us at a distance with this combination of movements of solid bodies, like the heavenly bodies, or projectiles.

But Redfield's purely experimental laws should not in any case be understood as referring to a fluid mass which is always the same, animated by these two movements. They refer to aerial masses which are always changing and always succeeding each other in this same gyratory apparatus.

From this time rational mechanics was of no assistance; this problem had not even been suggested then, or if it was suggested for an instant it was considered insoluble in the condition of the science at that time.

Meteorology was equally silent; there was known only the centripetal movement which was produced towards a center of rarefaction, and which might in certain cases, determine above this center the ascension (quite insignificant) of a column of air whose temperature was greater by several degrees than that of the surrounding air.

Evidently this last phenomenon, in which there is neither the gyration nor the translation which characterize whirling movements without exception, from the tempest to the smallest *trombe*, has no relation to the question. Something must be looked for. It is this something else which I have proposed. I think I have shown in the first paper of this series that Redfield's laws can be interpreted in but one way—by the conception of descending whirls with vertical axes, originating in the upper currents of the atmosphere, following exactly the thread of the current, transporting in their spirals and concentrating below on the ground a part of the enormous energy with which these currents are animated.

In the second article we have seen that *trombes* and tornadoes

are linked to the same conception. Here the demonstrations are striking. The absence of all centripetal movement is rendered sensible to the eye by the figure of revolution which defines these phenomena so clearly. Their circular gyrations are inscribed upon the ruins of the territory which they devastate in characters whose significance it is henceforth impossible to misunderstand. They are actually seen to descend from the clouds, when meteorologists persist in making them ascend.

The third article has shown the same causes and mechanical nature in thunder-storms and hail. The atmosphere is traversed by tempestuous movements under the most varied forms. All are linked, however, without effort, to one and the same conception. This opens a new field for rational mechanics; mathematical analysis will succeed sooner or later in making it fruitful, for to-day the interpretation of facts, freed from prejudice and arbitrary hypothesis has shown them the way.

As to Redfield's laws, they are becoming what they should have been fifty years ago—i. e., the broadest and most solid experimental basis of dynamic meteorology. If I succeed in definitely gaining their cause, there will be no longer question of correcting them or of changing the rules of navigation derived from them, but only of studying the modifications which storms undergo while traversing their gigantic trajectories.

"Je remercie, en terminant, Messieurs les Directeurs de l'American Meteorological Journal d'avoir si libéralement accueilli mon travail. Je remercie surtout Madame Harrington qui a bien voulu traduire en Anglais ces trois longues pièces écrites par un Francais dans l'espoir de trouver aux Etats-Unis des juges impartiaux et profondément intéressés dans ces questions."

EDITORIAL NOTE.

The tardiness in the appearance of this number is due to the illness of the managing editor and to delay in obtaining cuts ordered. The latter delay was so great that an interesting article on balloon ascents for meteorological purposes, which should have appeared in this number, is delayed until the next.

We finish in this number the articles of M. Faye on cyclones, tornadoes and water-spouts. They began in the number for

November, 1889, and, together, form the most complete exposition of M. Faye's theory which has yet been put in print. We hope that it will attract the attention of English-speaking meteorologists, and we are confident that criticism of it would be not unwelcome to its distinguished author.

We have printed the state tornado charts of Lieutenant Finley as a contribution to American meteorology, and also as an index to American tornadoes. It appears, however, that New York, by some oversight, escaped attention. It will be given space in an early number.

CORRESPONDENCE.

A NORTHERN BIRD DRIVEN SOUTHWARD.

TO THE EDITOR: On Sunday, January 18, a splendid specimen of the great northern shrike made its appearance in Jewett City, Connecticut. These birds are natives of much higher latitudes than this, and their appearance here is probably due to the extreme cold in the north. These birds are to a certain degree birds of prey, as their food consists of sparrows and field mice, which they capture and transfix upon some near-by thorn bush. They are about the size of the robin, though their tail is much longer and the beak is hooked. The plumage is gray and white, with a black stripe extending from the eye down the side of the head and neck. H. J. COX.

New Haven, Conn., Jan. 19, 1891.

PUBLICATIONS RECEIVED.

"The Laws of Storms Considered with Special reference to the North Atlantic." Everett Hayden. Octavo, thirteen pages, five charts. Abstract of a lecture before the National Geographic Society, published in the *National Geog. Mag.*, Volnum II, Number III.

"Quarterly Journal of the Royal Meterological Society." July, 1890. This number has much photographic literature; an account of the cold period of March, 1890, by Mr. C. Harding; a discussion of weather forecasting by monthly averages, by Mr. A. E. Watson; and an account of the pole-star recorder by Mr. Rotch, and bibliographical notes.

THE

THEORY OF SUBSTITUTIONS

AND ITS

APPLICATIONS TO ALGEBRA.

BY

DR. EUGEN NETTO,

Professor of Mathematics in the University of Giessen.

Revised by the Author and Translated with his Permission
by F. N. Cole, Ph. D., Asst. Prof. of Mathematics
in the University of Michigan.

ANN ARBOR, MICHIGAN:
REGISTER PUBLISHING COMPANY.
The Inland Press.
1890.

To the present day no treatise on the Theory of Substitutions has appeared in the English language. The student desiring to gain a knowledge of this fundamentally important branch of mathematics has been obliged to consult the classical but difficult "Traité" of Jordan, or the more elementary works of Serret and Netto.

The last-named author's "Substitutionentheorie," published in 1882, contains a remarkably clear, elegant, and attractive presentation of this subject, and the translator has long felt that an English edition of this work would be an acceptable addition to mathematical literature. And he is especially gratified to be able to announce that Dr. Netto has not only consented to the present translation, but has agreed to revise the first edition thoroughly, and that all proof-sheets of the translation will pass under his eye before publication, so that the translation is in fact a second revised edition.

To indicate the scope and nature of the work the preface and table of contents of the first edition are here added.

PREFACE TO THE FIRST EDITION.

The presentation of the Theory of Substitution here given differs in several essential features from that which has heretofore been customary. It will accordingly be proper in this place to state in brief the guiding principles adopted in the present work.

It is unquestionable that the sphere of application of an Algorithm is extended by eliminating from its fundamental principles and its general structure all matters and suppositions not absolutely essential to its nature, and that through the general character of the objects with which its deals, the possibility of its employment in the most varied directions is secured. That the theory of the construction of groups admits of such a treatment is a guarantee for its far-reaching importance and for its future.

If, on the other hand, it is a question of the application of an auxiliary method to a definitely prescribed and limited problem, the elaboration of the method will also have to take into account only this one purpose. The exclusion of all superfluous elements and the increased usefulness of the method is a sufficient recompense for the lacking, but not defective, generality. A greater efficiency is attained in a smaller sphere of action.

The following treatment is calculated solely to introduce in an elementary manner an important auxiliary method for algebraic investigations. By the employment of integral functions from the outset, it is not only possible to give to the Theory of Substitutions, this operating with operations, a concrete and readily comprehended foundation, but also in many cases to simplify the demonstrations, to give the various conceptions which arise a precise form, to define sharply the principal question, and—what does not appear to be least important—to limit the extent of the work.

The two comprehensive treatises on the Theory of Substitutions which have thus far appeared are those of J. A. Serret and of C. Jordan.

The fourth section of the "Algèbre Supérieure" of Serret is devoted to this subject. The radical difference of the methods involved here and there hardly permitted an employment of this highly deserving work for our purposes. Otherwise with the more extensive work of Jordan, the "Traité des substitutions et des équations algébriques." Not only the new fundamental ideas were taken from this book, but it

is proper to mention expressly here that many of its proofs and processes of thought also permitted of being satisfactorily employed in the present work in spite of the essential difference of the general treatment. The investigations of Jordan not contained in the "Traité" which have been consulted are cited in the appropriate places.

But although many single particulars are traceable to this "Traité" and to these investigations, nevertheless the author is indebted to his honored teacher, L. Kronecker, for the ideas which lie at the foundation of his entire work. He has striven to employ to best advantage the benefits which he has derived from the lectures and from the study of the works of this scholarly man, and from the inspiring personal intercourse with him; and he hopes that traces of this influence may appear in many places in his work. One thing he regrets: that the recent important publication of Kronecker, "Grundzüge einer arithmetischen Theorie der algebraischen Grössen," appeared too late for him to derive from it the benefit which he would have wished for himself and his readers.

The plan of the present book is as follows:

In the first part the leading principles of the theory of substitutions are deduced with continual regard to the theory of the integral functions; the analytical treatment retires almost wholly to the background, since it is only employed later in reference to the groups of solvable equations.

In the second part, after the establishment of a few fundamental principles, the equations of the second, third and fourth degree, the Abelian and the Galois equations are discussed as examples. After this follows a chapter devoted to an arithmetical discussion the necessity of which is there explained. Finally the more general, but still elementary questions with regard to solvable equations are examined.

EUGEN NETTO.

TABLE OF CONTENTS.

[1ST EDITION.]

PART I.

THEORY OF SUBSTITUTIONS AND OF INTEGRAL FUNCTIONS.

CHAPTER I.

SYMMETRIC OR SINGLE-VALUED FUNCTIONS.—ALTERNATING AND TWO-VALUED FUNCTIONS.

CHAPTER II.

MULTIPLE-VALUED FUNCTIONS AND GROUPS OF SUBSTITUTIONS.

CHAPTER III.

THE DIFFERENT VALUES OF A MULTIPLE-VALUED FUNCTION AND THEIR ALGEBRAIC RELATIONS TO ONE ANOTHER.

CHAPTER IV.

TRANSITIVITY AND PRIMITIVITY.—SIMPLE AND COMPOSITE GROUPS.—ISOMORPHISM.

CHAPTER V.

ALGEBRAIC RELATIONS BETWEEN FUNCTIONS BELONGING TO THE SAME GROUP.—FAMILIES OF MULTIPLE-VALUED FUNCTIONS.

CHAPTER VI.

THE NUMBER OF THE VALUES OF INTEGRAL FUNCTIONS.

CHAPTER VII.

INVESTIGATION OF CERTAIN PARTICULAR KINDS OF GROUPS.

CHAPTER VIII.

ANALYTICAL REPRESENTATION OF SUBSTITUTIONS.—THE LINEAR.—GROUP.

PART II.

APPLICATION OF THE THEORY OF SUBSTITUTIONS TO THE ALGEBRAIC EQUATIONS.

CHAPTER IX.

THE EQUATIONS OF THE SECOND, THIRD AND FOURTH DEGREES.—GROUP OF AN EQUATION.—RESOLVENTS.

CHAPTER X.

THE CYCLIC EQUATIONS.

CHAPTER XI.

THE ABELIAN EQUATIONS.

CHAPTER XII.

EQUATIONS FOR WHICH RATIONAL RELATIONS EXIST AMONG THREE ROOTS.

CHAPTER XIII.

ON THE ALGEBRAIC SOLUTION OF EQUATIONS.

CHAPTER XIV.

THE GROUP OF AN ALGEBRAIC EQUATION.

CHAPTER XV.

ALGEBRAICALLY SOLVABLE EQUATIONS.

THE

MATHEMATICAL THEORIES

OF

PLANETARY MOTIONS.

BY

DR. OTTO DZIOBEK,

Privatdocent at the Royal Technical High School of Berlin-Charlottenburg.

TRANSLATED FROM THE GERMAN.

ANN ARBOR.
REGISTER PUBLISHING COMPANY.
1890.

PREFACE.

The problem of the motion of the heavenly bodies is of great importance in itself, but it is of especial importance to the mathematician. The attempts to solve it, though not entirely successful, have afforded occasion for a display of unsurpassed ability and have given a great impulse to mathematics. Analytical mechanics, beginning with Newton and receiving its final form from Lagrange, is especially indebted to this problem which afforded it the very foot-hold necessary for its advance, and though not yet completely solved, it has proved so fertile in suggestion and impulse that it has determined, to a great degree, not only the direction but also the rapidity of the advance of mathematics.

Hence, when it is desired to illustrate the abstract theories of analytical mechanics, the profundity of the mathematics of the problem of the motions of the heavenly bodies, its powerful influence on the historical development of this science, and finally the dignity of its object, all point to it as most suitable for this purpose.

This work is not so much intended for the specialist in astronomy as for the student of mathematics who desires an insight into the creations of his masters in this field. The lack of a text-book which would give, within moderate limits and in a strictly scientific manner, the principles of mathematical astronomy in their present remarkably simple and lucid form is undoubtedly the reason why so many mathematicians extend their knowledge of our planetary system but little beyond Kepler's laws. The author has endeavored to fill this gap and, at the same time, to produce a book which shall be so near the present state of the science that the latest investigations shall be included, and even the unsettled questions indicated.

The subject of the work is that part of celestial mechanics which treats of the motions of the heavenly bodies considered as gravitating points. This is the most important part, and it is fundamental for theories of rotation, of tides, and of the figures of bodies. The author hopes to treat of the latter in a separate work. The simplest processes, and those which best represent the present state of the science, have always been selected and especial care has been taken to guard against the brilliant hypotheses which the explorers of this field have so often indulged in but which are not suitable for a text-book. The farther

advance of the student is aided by the references to the original sources which are invariably given, and which have, almost without exception, been used by the author. Farther assistance in this direction is afforded by the sketch of the historical development of the subject which accompanies each important sub-division of the work.

At the end of the book are several tables which contain those numerical data, as given by Leverrier and Newcomb, which are used in the general theory.

For the pecuniary aid which permitted the necessary studies and the publication of this work, the author begs to return his sincerest thanks to his Excellency, Dr. von Gossler, minister for religious, educational and medical affairs.

DR. DZIOBEK.

CHARLOTTENBURG, September 1, 1888.

NOTE BY THE TRANSLATOR.

The author kindly consented to read the proof of this translation. Many changes have been introduced by him.

M. W. H.

CONTENTS.

FIRST DIVISION.

SOLUTION OF THE PROBLEM OF TWO BODIES; FORMATION OF THE GENERAL INTEGRALS FOR THE PROBLEM OF n BODIES; ALGEBRAIC TRANSFORMATIONS FOR THIS PROBLEM.

SECOND DIVISION.

THE GENERAL PROPERTIES OF THE INTEGRALS.

THIRD DIVISION.

THE THEORIES OF PERTURBATION.

EXCERPTS FROM NOTICES BY THE SCIENTIFIC PRESS.

Weidenmann's *Annalen der Physik and Chemie* (*Beiblätter*).

"The presentation is clear and not difficult, although not elementary. It is, in every sense, abreast with the latest progress in analysis. To the physicist the first and second parts are of especial interest."

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"The author's standpo nt is purely mathematical; the Problem of Three Bodies is considered in its general form, and in such a way as to show the progress toward its solution when applied to the Solar System. The presentation of difficulties of application and the method of overcoming them lies outside the author's purpose. * * * Although at this time most astronomers are occupied with the development of this latter part [the application numerically] of the Theories of Perturbation, the meritorious work of Mr. Dziobek will nevertheless be read with interest in astronomal circles."

MATHEMATICAL THEORIES OF PLANETARY MOTIONS.

FIRST DIVISION.

Solution of the Problem of Two Bodies. Formation of the General Integrals for the Problem of n Bodies. Algebraic Transformations of this Problem.

1. Newton's Law of Gravitation. Motion of Two Points Subject to It.

Newton's law of gravitation is the point of departure in mathematical investigations of the motions of the heavenly bodies. This law reads as follows:

Each particle of matter attracts any other particle with a force whose magnitude is directly as the product of their masses and inversely as the square of their distance from each other.

Assume that P_1 and P_2 are two gravitating particles, the coordinates and mass of the first, referred to stationary rectangular coordinates, are x_1, y_1, z_1, m_1, and those of the second are x_2, y_2, z_2, m_2, then the distance between them is

$$(1) \qquad r = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2}$$

and this is to be considered as always positive. The total force between the bodies, according to Newton's law,

$$= k^2 \frac{m_1 m_2}{r^2},$$

where k is a constant whose magnitude depends on the selected units of mass, distance, and time.

Since the two particles attract each other, the direction of action is along the line which joins them. The action of P_2 on P_1 has the direction from P_1 to P_2 and its direction cosines are

$$\frac{x_2 - x_1}{r}, \quad \frac{y_2 - y_1}{r}, \quad \frac{z_2 - z_1}{r}.$$

The direction of the action of P_1 on P_2 is exactly the reverse, and its direction cosines are

$$\frac{x_1 - x_2}{r}, \quad \frac{y_1 - y_2}{r}, \quad \frac{z_1 - z_2}{r}.$$

The components of the first force in the direction of the coordinate axes are therefore

$$k^2 m_1 m_2 \frac{x_2 - x_1}{r^3}, \quad k^2 m_1 m_2 \frac{y_2 - y_1}{r^3}, \quad k^2 m_1 m_2 \frac{z_2 - z_1}{r^3}.$$

The components of the second force are, also,

$$k^2 m_1 m_2 \frac{x_1 - x_2}{r^3}, \quad k^2 m_1 m_2 \frac{y_1 - y_2}{r^3}, \quad k^2 m_1 m_2 \frac{z_1 - z_2}{r^3}.$$

Consequently the differential equations of the motion of the two points are, when t represents the time,

$$(2) \quad \left\{ \begin{array}{l} m_1 \dfrac{d^2 x_1}{dt^2} = k^2 m_1 m_2 \dfrac{x_2 - x_1}{r^3}, \\ m_1 \dfrac{d^2 y_1}{dt^2} = k^2 m_1 m_2 \dfrac{y_2 - y_1}{r^3}, \\ m_1 \dfrac{d^2 z_1}{dt^2} = k^2 m_1 m_2 \dfrac{z_2 - z_1}{r^3}, \\ \text{and also} \\ m_2 \dfrac{d^2 x_2}{dt^2} = k^2 m_1 m_2 \dfrac{x_1 - x_2}{r^3}, \\ m_2 \dfrac{d^2 y_2}{dt^2} = k^2 m_1 m_2 \dfrac{y_1 - y_2}{r^3}, \\ m_2 \dfrac{d^2 z_2}{dt^2} = k^2 m_1 m_2 \dfrac{z_1 - z_2}{r^3}. \end{array} \right.$$

These differential equations are valid for any system of coordinates. Hence the letters x, y, z, can be cyclically interchanged. Advantage will be taken of this to simplify the

manner of writing the succeeding equations, in that only one of the three equations will be written, leaving the others to be made from it by exchange of letters. These cases will be indicated by the sign *. Introducing this change, equations (2) become

$$(2) \qquad * \begin{cases} m_1 \dfrac{d^2x_1}{dt^2} = k^2 m_1 m_2 \dfrac{x_2 - x_1}{r^3}, \\ m_2 \dfrac{d^2x_2}{dt^2} = k^2 m_1 m_2 \dfrac{x_1 - x_2}{r^3}. \end{cases}$$

These are six total and simultaneous differential equations and the determination of the motion of the two bodies is reduced to their integration. As they are all of the second order their complete integration will introduce twelve arbitrary constants. That this number is necessary appears directly from the fact that, to make the problem a definite one, twelve conditions must be expressed, for instance, six coordinates and six component velocities, for any given instant.

To prepare for the integration of equations (2), add the first and fourth. This gives

$$* \quad m_1 \frac{d^2x_1}{dt^2} + m_2 \frac{d^2x_2}{dt^2} = 0.$$

Integrating this once, and calling the constant $*\alpha_x$, we get

$$(3) \qquad * \quad m_1 \frac{dx_1}{dt} + m_2 \frac{dx_2}{dt} = \alpha_x.$$

These equations, on a second integration, give

$$(4) \qquad * \quad m_1 x_1 + m_2 x_2 = \alpha_x t + \beta_x.$$

Equations (4), in which $*\alpha_x$, β_x are constants, have a simple interpretation. If the coordinates of the center of gravity of the two points, that is the point which divides their distance in the inverse ratio of their masses, are X, Y, Z, then

$$(5) \qquad * \quad X = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2},$$

and equations (4) become

$$(6) \qquad * \quad (m_1 + m_2) X = \alpha_x t + \beta_x.$$

From these equations it appears that *the center of gravity*

moves in a straight line with uniform velocity,—which is the law of the conservation of the motion of the center of gravity.

Returning to equations (2), if we refer P_2 to a moving system of rectangular coordinates parallel to the original with the origin constantly at P_1, and designate the coordinates of P_2 in the new system by x, y, z, we have

$$(7) \qquad * \quad x = x_2 - x_1,$$

and we observe that these equations are included in the right-hand members of equations (2).

Put therefore

$$(8) \qquad k^2 (m_1 + m_2) = \mu,$$

divide the first three equations of (2) by m_1, the second three by m_2, and subtract in pairs, and we get

$$(9) \qquad * \quad \frac{d^2x}{dt^2} = -\mu \frac{x}{r^3}.$$

These three equations by integration afford the six remaining constants and complete the solution of the problem. For, by solving (5) and (7) for $*x_1$, x_2, we have

$$(10) \qquad * \quad x_1 = X - \frac{m_2}{m_1 + m_2} x, \quad x_2 = X + \frac{m_1}{m_1 + m_2} x.$$

P_1 may be considered as representing the sun, P_2 the planet. Equations (9) then determine the (relative) motion of the planet about the sun, and the motion is as if the sun were fixed and the planet attracted by the sum of the masses of the two bodies.

To integrate (9), multiply the second by $-z$, the third by $+y$, and add. We thus get

$$y \frac{d^2z}{dt^2} - z \frac{d^2y}{dt^2} = 0.$$

This is at once integrable, and gives

$$(11) \qquad * \quad y \frac{dz}{dt} - z \frac{dy}{dt} = c\zeta_x,$$

where $c\zeta_x$ is the constant of integration.

These are the so-called sectorial integrals. $ydz - zdy$ is twice the area of the triangle in the plane of yz, whose angles are the origin, the projection of the point x, y, z, and the projection

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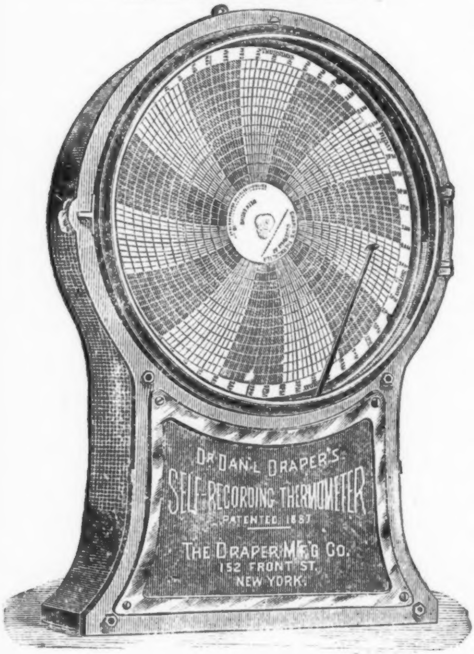

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These two books, the Prefaces and Tables of Contents of which are given just preceeding this page, and which give a good idea of these works, are now in preparation. Orders are solicited and will be filled as soon as the books are out. Prices: Dziobek, $3.50; Netto, $3.00. Address

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BY

H. A. HAZEN,

ASSISTANT PROFESSOR SIGNAL OFFICE.

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